$6
F.Im

FRACTURES AND DISLOCATIONS

IMMEDIATE MANAGEMENT, AFTER-CARE, AND CONVALESCENT TREATMENT WITH SPECIAL REFERENCE TO THE CONSERVATION AND RESTORATION OF FUNCTION

BY

PHILIP D. WILSON, A.B., M.D., F.A.C.S.

INSTRUCTOR IN ORTHOPÆDIC SURGERY, HARVARD MEDICAL SCHOOL

AND

WILLIAM A. COCHRANE, M.B., Ch.B., F.R.C.S. Edin.

UNIVERSITY TUTOR IN CLINICAL SURGERY, UNIVERSITY OF EDINBURGH

978 ILLUSTRATIONS

PHILADELPHIA AND LONDON
J. B. LIPPINCOTT COMPANY

COPYRIGHT, 1925, BY J. B. LIPPINCOTT COMPANY

PRINTED BY J. B. LIPPINCOTT COMPANY
AT THE WASHINGTON SQUARE PRESS
PHILADELPHIA, U. S. A.

TO

DOCTOR JOEL E. GOLDTHWAIT

WHOSE INTEREST SUPPLIED THE STIMULUS AND WHOSE
GENEROSITY PROVIDED THE OPPORTUNITY
FOR THIS WORK

FOREWORD

IT WOULD, I believe, express the feeling of the staff of the Fracture Service of the Massachusetts General Hospital to state that they are entirely in accord with the views of the authors as expressed in this work.

It is not possible, however, that all members of a large service should agree upon all minor details even though they have come to a remarkable unanimity of opinion on all the important facts. This divergence of opinions would, I believe, be quite unimportant.

DANIEL F. JONES, M.D., Chief of Staff,
Massachusetts General Hospital Fracture Service.

Digitized by the Internet Archive
in 2025

https://archive.org/details/bwb_S0-CJG-093

PREFACE

It is apparent to all particularly interested in the subject of fractures and dislocations that during the past decade a notable advance has been made in the treatment of these conditions. The greater perfection of the Roentgen ray and its now universal availability have established a new standard by which results must be judged and have emphasized the necessity of striving for complete anatomical restoration of injured structures. Additional experience under the industrial accident laws has been the means of obtaining information concerning the disabling effects of injuries and the results of treatment. This has disclosed in many instances unnecessary wastage of human material. The knowledge has also been acquired that with proper foresight and careful after-treatment, not only may disability time be considerably shortened, but much of permanent crippling may be entirely avoided. A new goal has thereby been set, that of complete functional restoration. The World War has also played an important part in progress, not only on account of the enormous experience it afforded and of the stimulus it gave for the introduction of new methods of treatment, but also because it aroused among members of the medical profession a greatly increased interest in skeletal injuries.

In the post-war period the lessons learned at such great cost have not been forgotten, and today in our larger hospitals débridement, direct skeletal traction, the Thomas splint, overhead suspension, fixation in positions of optimum function, and roentgenographic control are matters of common routine. However, this is of benefit to only a small proportion of the total number of cases of fracture and dislocation. The great majority of such injuries must perforce be treated by general practitioners of medicine, not in the well-equipped hospital, but in the physician's office or the patient's home. Notwithstanding the lack of suitable facilities, the same standard of treatment and the same quality of results as obtained in the best hospitals are demanded by both the public and the courts. Such results can be obtained only by the use of the most efficient procedures. The best tools must be placed within reach of every physician and he must be instructed in their use.

The objection is frequently raised that much of the newer apparatus is complicated and not available in the country and that the methods of treatment are too difficult to be used by the general practitioner. We do not believe that this criticism is substantiated by actual experience. The complexity is more apparent than real and disappears when familiarity is acquired. As far as availability is concerned this newer apparatus

may now be obtained from any of the larger surgical supply houses, and in case of an emergency it may be improvised with the aid of the village blacksmith in a minimum of time. The actual amount of equipment which the foresighted physician must keep on hand is small and comparatively inexpensive. In relation to the difficulties of the procedures we believe that the principles underlying them are relatively simple and we have confidence that the mechanical ability and ingenuity of the general practitioner may be counted upon to solve each problem as it arises.

In undertaking the preparation of the present volume the authors have attempted to make available the results of special experience in the treatment of these conditions, and to describe the methods, whether old or new, which have proved of greatest value in dealing with all the more common fractures and dislocations. It would have seemed presumptuous to have undertaken this task if it had involved merely a presentation of our own opinions. Actually what we have attempted is to report as faithfully as possible the practice of the group of surgeons constituting the staff of the Fracture Service of the Massachusetts General Hospital. This service, the later outgrowth of the Fracture Squad, previously organized by Dr. C. L. Scudder, took its present form in June, 1920, and is responsible for the treatment of all cases of fracture and dislocation admitted to the wards or cared for in the Out Patient Department of the Hospital. Under the leadership of Dr. Daniel F. Jones, Chief of the Staff, and of Dr. Robert B. Osgood, until recently Orthopædic Consultant, the Service has functioned with conspicuous success. A wealth of clinical material has been available for free discussions at the weekly staff visits. There has been an unusual opportunity to follow the results of treatment in the Out Patient Department. There has existed a feeling of utmost harmony among the members of the staff. All these factors have combined to make the Service profitable to patient and surgeon alike. The staff is composed of six surgeons, two being appointed from each of the two surgical services, and two from the orthopædic service; from the former, Drs. Arthur W. Allen, Torr W. Harmer, George A. Leland, Jr., and Henry C. Marble; from the latter, Drs. Zabdiel B. Adams and Philip D. Wilson.

Although in the beginning the work was approached from widely divergent viewpoints, this group experience has served to develop a remarkable unanimity of opinion concerning the relative value of different methods of treatment in the varying types of injury. Early in 1922 it was possible for the staff to agree upon and prepare an outline of methods of treatment. Later in the same year a conference of representative surgeons of wide experience from different sections of the United States and Canada was called to meet in Boston for the purpose of discussing standard methods for the treatment of fractures. Practically

all of the recommendations of the Massachusetts General Hospital Fracture Service, along with various valuable additions made by members of the conference, were incorporated in the Syllabus which was finally adopted. It was perhaps surprising and certainly gratifying to find such an unanimity of authoritative opinion.

In writing this book the authors have tried to keep in mind the needs of the general practitioner. It is for this reason that we have chiefly stressed non-operative methods of treatment. At the same time we have also endeavored to point out the indications for open surgical intervention and to state in a general way the nature of the operative procedure itself. We have also tried to outline as precisely as possible the various steps in the after-treatment looking to the most complete return of function in the shortest possible time. As our own clinical and teaching experience has made us realize the importance of a knowledge of anatomy for a proper understanding of all problems connected with fractures, we may have devoted a seemingly disproportionate amount of space to this subject. After consideration, however, our conviction remains that this emphasis is necessary.

Many of the roentgenograms and a certain number of the clinical photographs which serve as illustrations are of cases which have not been under our immediate care. In most of these instances it has not been possible to identify the surgeon in charge and to accord him proper credit. For this reason we have followed the policy of ascribing all the hospital cases, our own included, to the Fracture Service, to the members of which we wish to express our thanks for permission to use their material. We beg to acknowledge our special thanks to Dr. George W. Holmes, Roentgenologist, and to his clerical staff for the generous assistance which they have given in searching out and locating these films.

During the course of preparing the manuscript one of the authors has returned to Scotland and resumed work at the Edinburgh Royal Infirmary, happily without interruption of his duties as joint author. We have been pleased to note that the different environment and associations have not imposed the necessity of radically revising what had already been written, and that in respect to treatment, a substantial agreement exists in two institutions on opposite sides of the Atlantic. A certain number of our roentgenograms have been obtained from the Royal Infirmary and for permission to use these we express our grateful appreciation.

The photographs showing the application of splints and the construction of plaster of Paris apparatus were made in the laboratory of Surgical Research of the Harvard Medical School, with the kind permission of Dr. Harvey Cushing, Moseley Professor of Surgery, and of Dr. Elliott C. Cutler, Director of the Laboratory. We take pleasure in acknowledging our obligation to Messrs. Thomas Fogarty and Francis Cobb, the

Laboratory Assistants, for their aid in making the photographs. We wish also to express our appreciation of the services of Miss Margery Burnham who helped in the preparations of the illustrations, and of Miss Hannah Lissner who aided in arranging the manuscript.

Most of all we wish to acknowledge our great debt of gratitude to Dr. Robert B. Osgood, Professor of Orthopædic Surgery, Harvard Medical School, who has reviewed and criticised the manuscript, given invaluable suggestions for its improvement, and been ready with help at all times when aid was requested.

P. D. Wilson, 372 Marlborough St., Boston,
W. A. Cochrane, 24 Walker St., Edinburgh.

CONTENTS

CHAPTER PAGE

I.—PRINCIPLES OF TREATMENT 1
The Functional Viewpoint in Treatment, 1
Pathology in Relation to Treatment, 2
Relation of Anatomic Form to Function, 4
Methods of Treatment, 6
I. Reduction and Fixation Method, 6
II. Massage and Mobilization Method, 8
III. The Traction Method, 12
IV. The Operative Method, 18
Roentgenological Examination in Relation to Fractures, 22
Summary of Treatment of Fractures, 24

II.—EMERGENCY OR PRIMARY SPLINTING OF FRACTURES 27
Immediate Splinting and its Benefits, 27
Standardization of Splints and Methods for Emergency Use, 28
Methods of Applying Splints for Emergency Use, 32
I. Thomas Arm Splint, 32
II. Thomas Leg Splint, 32
III. Cabot Posterior Wire Splint, 32
IV. Hand and Wrist Splint, 33
V. Long Liston Splint, 33
VI. Bradford Frame, Snow-shoe Litter, etc., 35
VII. Pillow and Side Splints, 36

III.—COMPOUND FRACTURES AND DISLOCATIONS 38
General Considerations, 38
Wound Infection in General, 39
Mechanical Sterilization of the Wound, 40
Closure of the Wound by Primary, Delayed Primary, or Secondary Suture, 41
The Carrel-Dakin Method of Treating Infected Wounds, 42
B. I. P. Paste, 45
Latent Infection in Healed Compound Fractures, 46
Different Types of Compound Injuries, 47
I. Produced by External Violence, 47
II. Produced by Internal Violence, 48
Clinical Examination of Cases of Compound Injury, 48
Treatment of Compound Injuries, 49
I. With Uninfected Wounds, 51
II. Potentially Infected, 52
Methods of Fixation to be used in Injuries in the Various Regions, 58

IV.—INJURIES OF THE SHOULDER GIRDLE 59
Anatomical Considerations, 59
I. Fracture of the Clavicle, 63
II. Dislocations of the Clavicle, 73
Sterno-clavicular Dislocation, 73
Acromio-clavicular Dislocation, 74
III. Fractures of the Scapula, 78
Fracture of the Neck of the Scapula, 79

V.—INJURIES IN THE REGION OF THE SHOULDER 82
Anatomical Considerations, 82
I. Dislocations of the Shoulder, 89
Mechanism and Varieties, 90
Recurrent Dislocation, 96
Old-standing Dislocation, 97
Dislocation Associated with Fracture, 98

CHAPTER PAGE

V.—INJURIES IN THE REGION OF THE SHOULDER (Continued)

II. Injuries of the Upper End of the Humerus, 101
Fracture of the Surgical Neck, 102
Fractures with Displacement, 105
Fractures without Displacement, 112
Separation of the Upper Humeral Epiphysis, 113
Fracture of the Anatomical Neck, 120
Fracture of the Greater Tuberosity, 124
Compound Injuries in the Region of the Shoulder, 127

VI.—REGION OF THE UPPER ARM 129

Anatomical Considerations, 129
Fracture of the Shaft of the Humerus, 133
Treatment, 135
Delayed Union—Non-union, 150
Radial Nerve Paralysis, 151
Compound Fracture of the Humerus, 151

VII.—INJURIES IN THE REGION OF THE ELBOW 154

Anatomical Considerations, 154
I. Dislocation of the Elbow, 162
1. Posterior Dislocation of Both Bones, 164
2. Dislocation of the Head of the Radius, 171
Anterior Type of this Dislocation, 171
Posterior Type of this Dislocation, 174
Subluxation of the Radius or "Pulled Elbow," 174
II. Fractures of the Lower End of the Humerus, 175
1. Supracondylar Fracture, 176
2. Transverse Diacondylar Fracture, 176
3. Fracture of a Single Condyle, 177
4. Intercondyloid or "T" Fracture of the Lower End of Humerus, 178
5. Fracture of an Epicondyle, 178
6. Separation of an Epiphysis, 179
Diagnosis of Fractures of the Lower End of the Humerus, 180
General Principles of Treatment, 182
Treatment in Relation to Specific Fractures of the Lower End of the Humerus, 195
1. Supracondylar Fracture, 195
2. Transverse Diacondylar Fractures, 197
3. Fracture of a Single Condyle, 197
4. Intercondyloid or "T" Fracture, 197
5. Fracture of an Epicondyle, 202
6. Epiphyseal Separation, 202
III. Fracture of the Head and Neck of the Radius, 203
IV. Fracture of the Coronoid Process, 206
V. Fracture of the Olecranon, 206

VIII.—THE FOREARM 215

Anatomical Considerations, 215
I. Fracture of the Shaft of the Ulna, 220
II. Fracture of the Shaft of the Ulna Associated with Dislocation of the Head of the Radius, 222
III. Fracture of the Shaft of the Radius, 222
IV. Fracture of Both Bones, 226
Treatment of the Fractures of Bones of the Forearm, 228
1. General Considerations, 228
2. Dangers, 236
Treatment in Relation to Special Fractures of the Forearm, 237
I. Fracture of the Shaft of the Ulna, 237
II. Fracture of the Ulna with Dislocation of Head of Radius, 240

CHAPTER PAGE

VIII.—THE FOREARM (Continued)

III. Fracture of the Shaft of the Radius, 242
IV. Fracture of Both Bones, 244
Compound Fractures of the Forearm, 249

IX.—INJURIES OF THE WRIST AND HAND..... 250

Anatomical Considerations, 250
I. Fractures of the Lower End of the Radius, 262
1. Hyperextension Fractures, 262
a. Colles's Fracture, 262
b. Epiphyseal Separation, 285
c. Fractures of Lateral Articular Border and Radial Styloid, 285
d. Posterior Articular Marginal Fracture, 288
2. Flexion Fractures, 289
a. Smith's Fracture (Colles's Fracture Reversed), 290
b. Anterior Articular Marginal Fracture, 292
c. Epiphyseal Separations, 292

II. Injuries of the Wrist-joint, 292
1. Dislocation of Inferior Radio-ulnar Joint, 292
2. Dislocation of the Radio-carpal Joint, 294
3. Carpal Injuries, 295
a. Fractures of the Scaphoid, 295
b. Dislocation of the Semilunar, 301
c. Other Fractures and Dislocations of the Carpus, 304
4. Carpo-metacarpal Dislocations, 305
5. Compound Injuries in the Region of the Wrist, 306

III. Injuries of the Metacarpals and Fingers, 307
1. Fracture of the Metacarpal Bones, 307
a. Bennett's Fracture, 307
b. Fracture of the Metacarpal Shaft, 309
c. Other Fractures of Metacarpal Bones, 313
2. Dislocation of the Metacarpo-phalangeal Joints, 313
a. Dorsal Luxation of the Proximal Phalanx of the Thumb, 314
3. Interphalangeal Dislocations, 317
4. Fracture of the Phalanges, 317
5. "Baseball Finger," 319
6. Compound Injuries of the Fingers and Thumb, 321

IV. The Treatment of Stiff Hands, 323

X.—THE VERTEBRAL COLUMN..... 327

Anatomical Considerations, 327
Injuries of the Vertebral Column, 341
General Considerations, 341
I. Isolated Dislocation of an Articular Process, 343
II. Traumatic Lesions of the Atlas and Axis, 347
III. Traumatic Spondylolisthesis, 351
IV. Isolated Fractures of the Spinous Processes or Laminæ, 355
V. Isolated Fracture of the Transverse Processes, 358
VI. Compression Fracture of the Vertebral Bodies, 363
Traumatic Spondylitis, 371
VII. Total Dislocation and Fracture-dislocation of the Spine, 372
VIII. Injuries of the Spinal Cord Associated with Fractures and Dislocations of the Vertebral Column, 374
Lumbar Puncture, 377
Total Transverse Lesions of the Spinal Cord, 378
Partial Lesions of the Cord, 382
Treatment of Spinal Cord Injuries, 384
1. Immediate Treatment, 384
2. Remote Treatment, 388

CHAPTER PAGE

XI.—INJURIES OF THE BONES OF THE FACE 392

General Considerations, 392
I. Fracture of the Nasal Bones, 392
II. Fracture of the Malar Bone and Zygomatic Arch, 397
III. Fracture of the Superior Maxilla, 398
IV. Injuries of the Mandible, 400
1. Dislocation of the Mandible, 402
2. Fractures of the Mandible, 403

XII.—INJURIES OF THE THORAX 412

Anatomy of the Thorax, 412
I. Fracture of the Ribs, 414
II. Fracture of the Costal Cartilages, 421
III. Fracture of the Sternum, 421
IV. Intrathoracic Complications, 422
V. Open Wounds of the Chest Wall, 425

XIII.—INJURIES OF THE PELVIS 426

Anatomy of the Pelvis, 426
Types of Pelvic Injury, 428
I. Injuries of the Pelvic Ring, 429
1. Fracture of Rami of Pubis, 431
2. Multiple Fractures of Pelvic Ring, 431
3. Separation of Symphysis Pubis, 432
4. Dislocation of Sacro-iliac Joint, 433
II. Isolated Fracture of the Bones of the Pelvis not Affecting the Continuity of the Pelvic Ring, 442
1. Fractures of the Ilium, 442
2. Isolated Fracture of the Ischium, 444
3. Isolated Fracture of the Sacrum, 445
4. Isolated Fracture of the Coccyx, 446
III. Fractures of the Acetabulum, 446

XIV.—INJURIES OF THE HIP 447

Anatomy of the Hip, 447
I. Dislocation of the Hip, 457
II. Fracture of the Acetabulum with Intrapelvic Displacement of the Head of the Femur, 472
III. Separation of the Capital Epiphysis of the Femur, 479
IV. Fracture of the Neck of the Femur, 483
V. Intertrochanteric Fracture of the Femur, 513
VI. Pertrochanteric Fracture of the Femur, 515
VII. Fractures of the Trochanters, 515

XV.—FRACTURES OF THE SHAFT OF THE FEMUR 520

Anatomical Considerations, 520
Fractures of the Shaft of the Femur, 521
Treatment, 531
Skeletal Traction, 546
Treatment of Fractures of the Femur at Different Levels, 556
After-treatment of Fractures of the Femur, 561
Fracture of the Femur in Children, 568
Open Operative Treatment, 573
Compound Fractures of the Femur, 577

XVI.—INJURIES IN THE REGION OF THE KNEE 578

Anatomy of the Knee, 578
I. Fractures of the Femoral Condyles, 584
II. Separation of the Lower Femoral Epiphysis, 588
III. Fracture of the Tuberosities of the Tibia, 590
IV. Separation of Upper Epiphysis of the Tibia, 597

CHAPTER PAGE

XVI.—INJURIES IN THE REGION OF THE KNEE (Continued)

V. Separation of the Tibial Tubercle, 599
VI. Fracture of the Patella, 600
VII. Dislocation of the Patella, 610
VIII. Dislocation of the Knee, 613
IX. Internal Derangements of the Knee-joint, 617
1. Injury of the Lateral Ligaments, 617
2. Injuries of the Semilunar Cartilages, 620
3. Injury of the Crucial Ligaments, 627
4. Fracture of the Tibial Spine, 630
5. Injury of the Infrapatellar Fat Pad, 631
6. Loose Bodies, 634.

XVII.—FRACTURES OF THE SHAFT OF THE TIBIA AND FIBULA..... 638

Anatomical Considerations, 638
I. Fracture of the Shaft of the Fibula (Unassociated with Injury of the Ankle-joint), 644
II. Fracture of the Shaft of the Tibia Alone, 645
III. Fracture of Both Bones of the Leg, 648
Treatment, 650

XVIII.—INJURIES IN THE REGION OF THE ANKLE..... 689

Anatomical Considerations, 689
I. Sprain of the Ankle, 692
II. Fractures of the Tibia and Fibula Involving the Ankle-joint, 697
1. Fracture by External Rotation of the Foot, 699
2. Fracture by Abduction of the Foot (Pott's Fracture), 700
3. Fracture by Adduction of the Foot, 701
4. Fracture by Posterior Displacement of the Foot, 702
Separation of the Epiphyses, 704
Diagnosis of Ankle Fractures, 704
Treatment of Ankle Fractures, 708
III. Dislocations of the Ankle-joint, 721
IV. Compound Injuries of the Ankle, 727

XIX.—INJURIES OF THE FOOT..... 731

Anatomical Considerations, 731
I. Fracture of the Astragalus, 744
II. Fractures of the Os Calcis, 745
1. Separation of Epiphysis or Avulsion Fracture of the Posterior Portion of the Os Calcis, 745
2. Fracture of the Sustentaculum Tali, 745
3. Fracture of the Body of the Os Calcis, 749
III. Dislocations of the Calcaneo-astragalo-scaphoid Articulation, 758
1. Incomplete or Subastragaloid Dislocation, 758
2. Total Dislocation of the Astragalus, 761
IV. Fracture of the Bones of the Anterior Tarsus, 762
V. Mediotarsal Dislocations, 763
VI. Tarso-metatarsal Dislocations, 764
VII. Fracture of the Metatarsal Bones, 765
VIII. Fracture of the Phalanges, 768
IX. Fracture of a Sesamoid of the Great Toe, 769
X. Dislocation of the Metatarso-phalangeal Articulation, 771
XI. Dislocation of the Phalanges, 772

FRACTURES AND DISLOCATIONS

CHAPTER I

PRINCIPLES OF TREATMENT

THE FUNCTIONAL VIEWPOINT IN TREATMENT

Goal of Treatment.—In traumatic lesions of the bones and joints, as in other disabilities, the goal of treatment is complete functional restoration in the shortest possible time. The function of bone is to support the soft parts and provide a mechanism for the action of muscles and joints. Rigidity is a prime requisite and in the event of fracture the restoration of this by solid union of the fragments is an obvious necessity. Preservation of the original anatomic form is equally important in order to prevent deformity and maintain unaltered the normal muscle and joint mechanism.

Requirements for Recovery.—While strong union and correct alignment are essential for a good result, these are not the only requisites, the ability to function being equally dependent upon a healthy condition of the muscles and joints and a normal nerve and blood supply. The patient who is left with a stiff and useless hand following a fracture of the wrist finds little consolation for that fact in the knowledge that the bones are solidly healed and in perfect alignment. Disability continues until there has been complete recovery of all the functions, and from the standpoint of treatment it is just as important to obtain active muscles, supple joints, and a normal blood supply as it is to secure accurate reposition and firm union of the bones.

Therapeutic Conflict.—It is just this multiplicity of therapeutic objectives which constitutes the crux of the entire problem of fracture treatment. A paradoxical situation is created by the fact that the best way of attaining one goal is often the worst way of reaching the other. In order to prevent displacement of the bones during the process of healing, immobilization is necessary; but, on the other hand, movement is essential for the maintenance of an active circulation and a healthy condition of the musculo-articular apparatus. The surgeon must find a way to reconcile these apparently conflicting interests, and by so doing he will not only achieve more perfect results, but will also greatly shorten the periods of disability.

PATHOLOGY IN RELATION TO TREATMENT

The key to the understanding of fracture treatment lies in a knowledge of the pathology of the lesion and of the changes that occur during the process of repair.

Bone Repair.—When a bone is broken, a condition of traumatic inflammation is produced. Hemorrhage occurs from the torn vessels of the marrow and periosteum, and a blood clot forms between the ends of the bones. Newly-formed vessels, leucocytes, and fibroblasts (osteogenic cells)—the last proliferating from the marrow and periosteal cells—soon permeate the clot and transform it into granulation tissue. The osteogenic cells arrange themselves concentrically in the recesses of the capillary loops and by virtue of their bone-forming function, secrete a homogeneous matrix in which lime salts are deposited. These foci of newly-formed bone unite with one another to form a network of spongy bone (callus). The callus is at first large and soft, but, as the density of the newly-formed bone increases, it gradually undergoes a process of reconstruction and absorption which has for its object the restoration of the normal outline and structure.

Factors Influencing Callus Formation.—The character and amount of the callus is influenced by the extent of the damage to the bone, the degree of displacement, the amount of motion permitted between the fragments, the presence or absence of infection, and the extent of vascular disturbance. A vigorous circulation is of prime importance in the formation of callus and the frequent occurrence of non-union in fractures of both bones of the leg is usually explained on the ground of insufficient blood supply following injury to the nutrient vessels. With much comminution or displacement, the size of the callus may be excessive, and, depending upon its situation, may cause mechanical interference with movement. Championnière has stated that some motion between the fragments is essential for the formation of healthy callus, but certainly the amount of the motion must be reduced to a minimum. It must not go beyond the stage of gentle stimulation of the granulation tissue. Gross movement between the fragments favors non-union.

Extra-osseous Injury.—The injury in a case of fracture is rarely confined to the bone alone, but practically always involves the adjacent soft parts to a greater or less extent. Extreme examples of this are seen in compound fractures from internal violence in which all the overlying structures are torn and there is direct communication from outside with the bone. In simple fractures, although the extra-osseous injury is less evident, it is present, nevertheless, and may be caused by the direct action of external trauma, or indirectly by the displacement

of the fragments. Not only are muscle and fascia lacerated, but there may be also serious injury of nerves and vessels. As a rule, the greater the degree of displacement, the greater is the extent of the damage. Aside from the actual injury of the soft parts, there is widespread infiltration of the tissues with blood.

Healing is marked by the formation of scar tissue and the absorption of the products of inflammation. The relative activity of these two processes can be considerably influenced by treatment. Immobilization causes circulatory stasis and thus interferes with the absorptive process, while massage and mobilization favor absorption and lessen the amount of scar tissue. If this phase of the injury is ignored in the treatment, excessive fibrosis results, with adhesion of the muscular layers, and this may seriously hinder the recovery of function.

Cause of Symptoms.—In this connection the essentially neurological nature of the phenomena which accompany fractures and dislocations should be emphasized—namely, the pain, muscle spasm, swelling, and limitation of joint motion. Most of the œdema in fractures occurs as a result of vasomotor paralysis. The pain is chiefly produced by muscle spasm. The muscle spasm is mainly protective and of a reflex nature similar to that seen in acute abdominal conditions. With the fixation of the muscles necessarily goes the limitation of joint motion.

Need of Immediate Treatment.—It will be well at this point to state two fundamental rules in the treatment of fractures and dislocations, because of their underlying pathological and physiological basis.

1. Fractures and dislocations should be immobilized immediately, on the spot where injury occurs, by some temporary but effective splinting method.

2. The displacement should be reduced and the definitive treatment applied at the earliest possible moment.

The reasons for applying treatment as early as possible are fairly obvious. Immediate emergency splinting protects the soft parts from injury during transit and prevents increase of deformity. Muscle spasm plays a large part in causing displacement and is at a minimum immediately after injury. Effective splinting at this period prevents displacement, so to speak, before it actually occurs. Correction of deformity becomes increasingly difficult with the lapse of time. The muscles become infiltrated with blood and exudate and lose their elasticity. At the end of twenty-four hours it becomes almost impossible to reduce certain severe displacements, and the earlier the treatment is applied, the easier it is to obtain restoration of normal alignment. On the other hand, with delay, manipulative reduction, even though it be successful, is sure to add fresh trauma to already injured tissues.

RELATION OF ANATOMIC FORM TO FUNCTION

Importance of Securing Reposition.—Every effort should be made to secure alignment and to prevent displacement. The report of the Fracture Committee of the British Medical Association [1] upon the late results of fractures states that a good anatomical result and a good functional result go together in over 90 per cent. of 1736 examined cases. They state that "no method, whether operative or non-operative, which does not promise a good anatomical result should be accepted as a matter of choice." Fair and even good functional results sometimes accompany a poor anatomical result, but usually only after prolonged disability time and when the particular and special types of deformity that lead to disuse have been avoided.

Disabling Deformity.—Angular deformity or gross displacement with overriding are particularly likely to result in functional impairment, because they impair the muscular adjustment and disturb the body statics. From the mechanical standpoint, all parts of the body are related and no part can be used wrongly without other parts suffering. The stability of the joints depends upon the balanced action of antagonistic muscle groups, and the above types of deformity are particularly apt to cause disturbance of this balance, with resulting joint strain. Angular deformity alters the normal line of the axes of the joints, and the component parts have then to work in wrong adjustment and with uneven bearing. Simple lateral displacement without shortening, provided that there is no angular deformity and that there is sufficient contact of the bone ends to insure union, is much less likely to cause disability than the types of malunion previously mentioned.

Situation of Deformity.—In estimating the disabling character of various deformities, it is important to view them in the light of their situation. If the fracture is situated in close proximity to a joint, even slight displacement may cause trouble because of mechanical impingement and limitation of motion or interference with the gliding mechanism of the tendons. Fractures of the upper extremity ought not to be judged from the same standpoint as those of the lower extremity because of the difference in the functional requirements of the two parts. The arm is not exposed to the heavy constant strain imposed by the function of weight-bearing as in the case of the leg. In the former, deformity which limits mobility is much more apt to cause serious disability than that which merely causes faulty alignment of the shaft. In the case of the leg, the ability to bear weight without pain requires above all that the joints retain their normal axes; otherwise, static strain, traumatic arthritis, and flat foot are apt to develop.

[1] Report of Committee on Treatment of Simple Fractures. *Brit. Med. Journ.*, Nov. 30, 1912.

Malunion in Children.—Similarly, there is a difference, depending upon whether one is dealing with a child or an adult. Although the statement should be made with all possible reservation, it is generally true that malunion in the former is much less liable to cause permanent bad effect than similar deformity in an adult. Children exhibit marvelous powers of compensation, and the growth process itself may eradicate certain deformities (Fig. 1). Truesdell [2] has recently reported the end results in five cases of simple fracture of the femur at varying levels in children. These patients originally showed 6 mm. to 1.25 cm. of shortening, but when reëxamined years later, the deficit had not only been made good, but there was 1.25 to 2.5 cm. actual lengthening. Incidentally, the joints of children adapt themselves to new conditions readily, and there is much less danger of doing harm by prolonged fixation than in the case of adults. Juxta-epiphyseal and epiphyseal injuries are to be regarded seriously because of the danger of growth disturbance at a later date. Complete correction of deformity is important in such cases.

FIG. 1.—Old supra-condylar fracture of the humerus with malunion. Note the new bone formation from the stripping up of the periosteum. In this way, a new shaft is being formed. The lower end of the old shaft will be absorbed, and very satisfactory alignment obtained. This patient is a child, and the same thing cannot be expected in an adult. (Edinburgh Royal Infirmary.)

Wolff's Law.—Bony deformity and the visible prominence caused by callus tend to lessen or entirely disappear in time. This is in accordance with Wolff's law, which states that the internal and external configuration of bone is adapted to the function it performs. The sharp angles round off and new trabeculæ form along the lines of stress, but while this

[2] E. D. Truesdell, *Annals of Surg.*, Oct., 1921.

improves the appearance at the seat of deformity, it does not restore the normal axes of the joints or remedy the other ill effects of malunion.

METHODS OF TREATMENT

Although innumerable methods for the treatment of fractures have been described, in reality all of them are modifications or adaptations of four fundamental methods, each of which emphasizes a different underlying principle. These methods of treatment are known as reduction and fixation, massage and mobilization, traction, and open operative reduction.

I. REDUCTION AND FIXATION METHOD

Original Plan of Treatment.— This is the traditional method of treating fractures, and requires that the fracture be "set" by closed manipulative reduction and then retained in proper alignment by the immediate application of close-fitting rigid splints, which immobilize the joints above and below the lesion. According to the original conception, in order to obtain a good result, it was only necessary to reduce the fracture and then immobilize until solid union was obtained, no matter whether this required weeks or months.

Limitations.—Formerly this method of treatment was employed in nearly all cases of fracture, but we now know that its range of usefulness is limited and that only with fractures in certain locations or of certain types can deformity be corrected in this manner. Indeed, with other fractures, such as those of the shaft of the femur or humerus, or oblique fractures of the bones of the forearm or leg, even if primary correction be obtained, it is impossible to maintain the alignment, serious displacement developing later in spite of the most carefully applied retentive apparatus. This is due to the thick padding of soft parts, which prohibits direct fixation of the fragments, and to the spasm of the powerful muscles, which is the actual cause of the displacement. For this reason the method is chiefly applicable in the case of bones with large cross-sectional area and situated superficially.

Prolonged Fixation Undesirable.—A policy of complete and prolonged fixation is also undesirable because it ignores the circulation and the neuromuscular and articular apparatus. The resulting stagnation of the soft parts is quite unphysiological and may result in circulatory impairment of such extent as actually to delay or considerably impair union, particularly in fractures of both bones of the leg. By this method the machine is allowed to stop, and when this occurs, it can only be set in motion again with great difficulty, and too often with a handicap of atrophied muscles, stiff joints, and adherent tendons.

Present Modifications.—As the method is used at present, it has been modified to permit adequate treatment of the soft parts and joints. In order to shorten disability, it is essential to begin massage and mobilization early. This is generally possible without danger of causing displacement by removing one portion of the dressing and using the other as a support while treatment is applied. Massage is performed daily, and as soon as the bones begin to unite, the part may be carefully lifted from the splints and gentle movements of the joints permitted while the parts are supported.

In the modern treatment of fractures, the method still has a wide range of application, but chiefly in fractures of the forearm and wrist, hip, lower leg, and foot. When it can be successfully used, it possesses the very real advantage of simplicity, and also of not tying the patient to bed with cumbersome apparatus.

Dangers.—However, the employment of this method of treatment is attended by several dangers. First, there is risk of applying the splints too tightly, with resulting circulatory interference or pressure injury. Second, the reduction itself usually requires an anæsthetic and looms in the patient's mind as an operation. Under these circumstances, if complete reduction is not obtained by the first manipulation, there is always a tendency to let well enough alone and to content oneself with incomplete correction rather than advising a second attempt. Third, there is the danger of neglecting the soft parts and of not employing the necessary physio-therapeutic measures early enough.

Reduction.—Complete muscular relaxation, immobility of the patient, opportunity for careful examination, and deliberate manipulation are the conditions necessary for a successful reduction. In order to obtain them, anæsthesia is practically always indicated. The reduction itself should be performed with the greatest gentleness in order to avoid further injury of the soft parts and the danger of converting a simple fracture into a compound injury. The procedures used are either traction and countertraction with local manipulation of the displaced bones, or the method of angulating the fragments to secure end-to-end approximation followed by extension. The latter method involves considerably more trauma than the first, but sometimes is the only means of securing replacement. Whenever possible, manipulation should be performed with the aid of direct fluoroscopic control.

Fixation.—As a rule, it is much easier to secure reduction than it is to maintain the correct alignment of the fragments during the application of the retentive splints. A considerable amount of manipulation is often necessitated by this part of the procedure, and it is at this stage that displacement occurs in many cases of failure. To avoid this danger, particularly when dealing with a fracture of the leg or of both bones of

the forearm, it is often advisable to apply strong traction to the foot or hand by means of bandage or other mechanical device until the apparatus is in place.

The writers have a decided preference for plaster of Paris as a splinting material whenever it meets the indications, because of its great adaptability and the fact that it can be made to conform exactly to the part. Plaster may be used either in the form of moulded splints or as a solid circular casing. The latter should usually be split immediately in order to prevent any chance of circulatory interference in case of swelling.

OPTIMUM POSITIONS FOR FIXATION AND FUNCTION

Position for Fixation.—It is a fundamental conception in connection with the immobilization of joints that certain positions are more favorable for the early recovery of motion than others. These are known as optimum positions for fixation, and in general they are those in which gravity is brought into play to aid in the restoration of motion. Thus, in the case of the elbow-joint, motion is much more quickly recovered from the position of acute flexion than from that of complete extension. In the former, gravity aids, while in the latter it hinders the recovery of movement. Other things being equal as far as the requirements of the lesion itself are concerned, the endeavor should always be made to immobilize in the optimum position for fixation.

Optimum Position for Ankylosis.—The position for fixation when eventual joint motion is expected should not be confused with the optimum position for function when a condition of joint ankylosis is anticipated. It is obvious that in case of the loss of movement at an articulation the usefulness of the part will depend directly upon the position of the joint when ankylosis occurs. When such an eventuality is to be expected, as in the case of infected joint fractures or other destructive conditions, the limb should be splinted in the position in which it is most frequently used and in which the best function may be expected. In the case of certain joints such as the shoulder, wrist, or ankle, the optimum positions for function and fixation may coincide. This is not necessarily so, however, and when they are dissimiliar, the consideration which should chiefly govern the selection of position is the nature and extent of the injury, and whether ankylosis is to be expected.

II. MASSAGE AND MOBILIZATION METHOD

First Use of the Method.— The importance of early massage and mobilization in the treatment of fractures was first emphasized by Lucas Championnière in his work, "Le Massage et la Mobilisation dans le Traitement des Fractures," published in 1889. Analyzing the lamentable results obtained at that time by the "Reduction and Fixation" method

of treatment, he raised a warning hand and vigorously advocated the cause of the soft parts, of the circulation, and indeed of the fracture itself. For various reasons, his writings were in the main misunderstood by the profession and were taken to mean that instead of the bone receiving all the attention and the soft parts being left to themselves the rôles should now be reversed and the soft parts receive attention while the fracture was neglected. In reality, Championnière advocated nothing of the kind, but used splints and operative measures as the case required.

Purpose.—However, he did demonstrate that in spite of the breaking of a part, it was still possible by the use of special methods to keep the machine running throughout the entire period of repair, and that in this way the process of rusting and general deterioration which always followed a considerable halt could be avoided. While due attention should be given to the bony injury, it was also necessary to preserve a vigorous circulation and the flexibility of the muscles and joints. Furthermore, he pointed out that by the use of his special massage treatment, pain was allayed and muscle spasm overcome, and thus bony deformity was corrected.

Not Ordinary Massage.— It is necessary to point out first of all that massage as employed by Championnière and later by Mennell, the chief exponent of the method in England, is of a very special though apparently simple kind, and it must not be confused with massage as generally understood. Ordinary massage is far too vigorous to be used successfully in the early treatment of fractures. In the words of Mennell,[3] the guiding rule of the professional masseur has been "to give the patient as much as he can stand," and the general misconception of what massage accomplishes, how it acts, and how it should be administrated has prevented its more general employment.

Relief of Pain.— The prime test of massage in the early treatment of fractures should be the relief of pain, for on the relief of pain, the muscle spasm, which is responsible for the pain, disappears also. This having been secured, reduction in some instances will occur almost spontaneously, and movement of the joints hitherto held rigid by muscle spasm is then possible. The relief of pain must be insisted upon and should never fail to follow massage as properly employed.

The immediate treatment of fractures by massage means in its very essence the slow and rhythmical repetition of a simple, delicate, and most gentle stroking of the skin, performed with uniform speed and monotonous regularity, and without the smallest deviation in direction. No pressure whatever should be exerted, the stroking being likened by Mennell to "little more than a caress," and "to the stroking of a cat." "So light should be the touch, so gentle the pressure that actual contact between

[3] James B. Mennell, "The Treatment of Fractures by Mobilization and Massage." Macmillan Co., 1911.

the hand and the injured part is almost imperceptible to the patient and practitioner alike," says Championnière. Reduction being thus possible from the relief of muscle spasm, splints and retentive apparatus are applied to maintain reduction, and the treatment is repeated daily, along with passive and active mobilization.

The term "mobilization" does not mean absence of restriction of motion or use, but follows the massage as a therapeutic measure in that pain and muscle spasm having been relieved, movements of the joints are now possible. "Movement is life" was Championnière's great dictum, but it is obvious that it would be useless to try to move joints when there is pain and muscle spasm. Massage is first necessary to render such movements possible and painless. Every joint of the injured limb should be moved, but wide range of motion is not necessary, as the principal effect of movement, in addition to maintaining joint flexibility, is to stimulate the circulation of the limb, the so-called "internal massage."

Action of Massage.— Wharton Hood attributed the relief of pain by massage to the unloading of the vessels of the limb, which, by reducing swelling, diminished the pressure on the nerve-endings. He stated that we must look upon the swollen part in the light of a sponge full of fluid, which is gradually emptied by pressure. If this were true, it would follow that the more vigorous the massage, the greater would be the benefit; whereas it is certain that the contrary is true, at least in the acute phase of the injury. Championnière attributed the relief of pain following massage in part to a decrease in the tension of the exudate at the seat of fracture, but thought the chief mode of action was in causing exhaustion of the sensory nerve endings by repeated cutaneous stimulation. Whether this explanation is correct or whether, as claimed by others, the effect is due to the direct stimulation of inhibitory influences, it is certainly a fact that the acute pain of a fresh fracture may be relieved by massage and that the lighter and more hypnotic its character the more striking is its effect.

In insisting upon the place of massage and mobilization in the treatment of fractures, Championnière rendered a service the importance of which has scarcely been recognized. The radical doctrine which he preached proved the starting point of a revolutionary change in the prevailing opinion with regard to these injuries; namely, that the more perfect was the immobilization, the better the process of healing. Not only did he show that a small amount of movement is not of itself detrimental to the formation of strong callus, but that it actually stimulates the process of repair.

Indications for Use.— Nowadays, massage and mobilization are regarded not as forming an independent system of treatment, but rather as therapeutic agents of known worth to be used as the case requires and conditions

permit. At one stage or another, they are employed in the treatment of nearly all fractures and have greatly contributed to the shortening of disability time and to the general improvement of functional results. In fractures without displacement, massage and mobilization should be used from the beginning, and in combination with light protective splinting they are the main factors in treatment. In fractures with displacement, while chief reliance is placed upon other methods to correct deformity and secure proper alignment at the same time, the importance of employing physio-therapeutic measures at the earliest possible moment is generally recognized. Particularly is it important to employ these agents in articular and para-articular fractures, as it is in these conditions that especially brilliant results have been obtained.

Technic of Massage.—The first step is to fix the part in a position of perfect rest and comfort, supported by sand bags or hard cushions. When the treatment of the exposed surface has been finished, the position should be reversed and the opposite side receive attention. The movement must be performed slowly (10–12 times a minute), beginning at the distal extremity and proceeding in a proximal direction. The movement of the hand must carefully follow the contour of the surface, and the stroke should commence distal to the point of actual contact and continue onward after contact is broken. The entire extent of the limb should be included in the massage, with the exception of the immediate vicinity of the fracture, which should in all cases be avoided. The quality of painlessness should above all others dominate the treatment, and the pressure used should be increased gradually, beginning with a touch so light that it is scarcely felt by the patient. It is usually possible after a short period of treatment to employ quite vigorous pressure, when in the beginning the patient was unable to bear anything but the slightest touch. Fifteen to twenty minutes a day is sufficient for the duration of the treatment, and it is often advantageous to make it less. In all cases it is necessary for the surgeon in charge to exercise personal supervision of the treatment and frequently to administer it himself. When union begins to be firm, a mild effleurage may be added to the program, but each treatment should begin and end with gentle superficial stroking.

Passive Motion.—Pain and muscle spasm having been relieved by the massage, it is now possible to proceed with the mobilization of the joints, care being exercised to avoid movement at the seat of fracture. Mobilization means the employment of both passive and active movements. The present tendency is to exclude passive motion and rely chiefly on active motion. This is not surprising in view of the harm that has been done in many cases by forceful pump-handle movements performed against the resistance of the patient's muscles. The true rationale of passive

motion is the restoration of the circulation by "internal massage" and the maintenance of joint flexibility, and to accomplish this, complete muscular relaxation is necessary. The movements must be painless, amplitude being sacrificed to frequency; no joint in the limb should be neglected, and all movements of which each joint is capable should be performed. They must be repeated smoothly and with monotonous regularity. Passive movements are not carried out as a separate part of the treatment, but follow and are combined with the massage.

Active Motion.—From the standpoint of maintaining the vitality of the muscles and the functioning power of the neuro-muscular apparatus, active voluntary movement is of greater value than passive motion, and it should form part of the daily routine. The simplest form of active exercise is that of independent muscle contraction without movement. The patient is instructed to tense or "set" certain muscle groups to the limit permitted without pain. This may be done without the removal of any dressing and can be carried out from the beginning in practically every case. Only a small amount of time is required to perform the exercises, and they should be repeated 200–300 times daily. Supported active motion consists in supporting the distal extremity of the limb while the patient moves the joint with his own muscles. In this way the load is removed, and strain of the fracture is prevented. By gradually decreasing the amount of actual support the load may be increased as union progresses. Unsupported movement should not be permitted until union is fairly solid, and then only with the limb placed in a position to avoid great strain. As the callus grows stronger, the amplitude of the movement may also be increased.

III. THE TRACTION METHOD

Purpose of Traction.— The use of continuous extension or traction constitutes the basic feature of the traction method. Although this method was used by Hippocrates and dates back to the earliest times, it was popularized chiefly by Buck,[4] Thomas, and Bardenheuer.[5] Its primary aim is to counteract muscle spasm, which is the chief cause of pain and displacement. Muscular relaxation is obtained and involuntary contraction prevented by means of a force continuously acting in the opposite direction in the longitudinal axis of the limb. Traction secures alignment by a pull in the direction of the normal anatomic lines and of itself aids in securing immobilization. The fascial envelope and the muscles enclosed within it are put under tension and thus act as close fitting splints to mould

[4] Gordon Buck, "Description of Improved Extension Apparatus." William Wood and Co., New York, 1867.

[5] Bardenheuer, *Arch. f. Klin. Chir.*, Vol. 83, No. 1, 1908.

the fragments into place. Reduction is brought about gradually without the necessity of manipulation or anæsthesia, and the alignment is then maintained by the continuous action of the traction force. When employed in conjunction with proper physio-therapeutic measures, it constitutes one of the most effective methods at our disposal for the treatment of fractures.

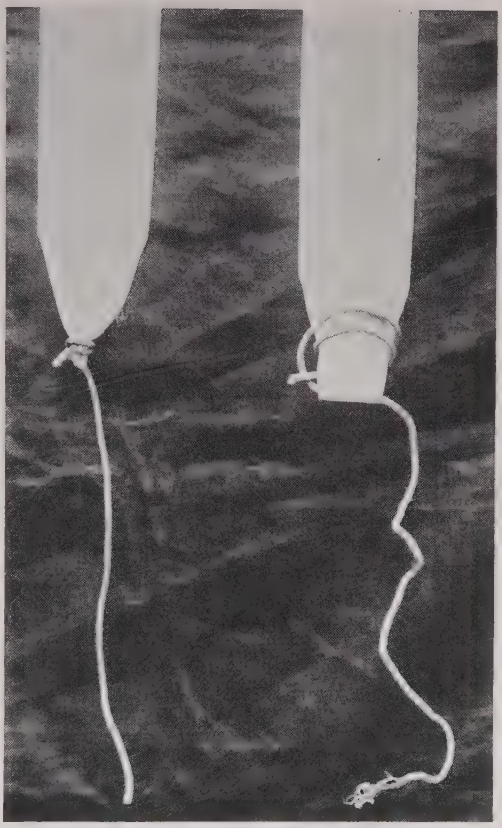


FIG. 2.—Adhesive traction strips. Method of preparing emergency traction strips, the cord being loosely tied in order to show the knot. The harder this knot is pulled, the more tightly it grips the adhesive plaster.

Traction Splints.— Traction alone, unless excessive force be used, is not of itself sufficient to prevent deformity under all conditions and should be combined with some form of fixation. It is in this connection that the various traction splints introduced by Thomas and Jones and so successfully used during the war have their special value. They are light and furnish efficient fixation, combined with maximum exposure of the part. In addition they provide integral traction, the circular end of the splint being thrust against the body as a point of countertraction, while the opposite end serves as a point of attachment for the traction bands, which are fastened under tension. The limb is supported as in a trough by slings fastened to the side bars of the splint. The line of pull remains unvaryingly in the direction desired, no matter what position the patient assumes, and hence much greater freedom of movement is permitted than by any other method. Thus, in fracture of the femur, it is possible to allow movement at the hip, and in fracture of the humerus, at the shoulder.

Skin Traction.—The method of securing extension by the use of adhesive bands fastened to the skin is generally understood and requires no special description. Adhesive plaster with flannel backing, known as "moleskin," conforms better to the irregularities of the surface and generally holds longer than ordinary adhesive plaster. (Fig 2.) As an alternative measure, one may use flannel traction strips which are

glued to the skin. (Fig. 3.) A strong, non-irritating glue is required, and the following preparation will be found satisfactory:

Heusner's Glue

Resin	50 parts
Alcohol	50 parts
Benzine (pure)	50 parts
Venice turpentine	5 parts

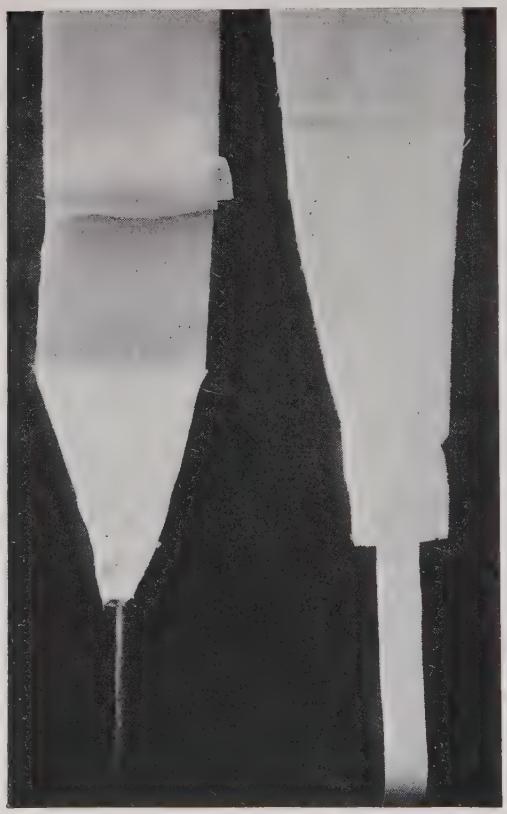


FIG. 3.—Traction strips. On left is shown an adhesive strip previously prepared in which a portion of cord is ravelled out and sewed to the plaster. On the right is a strip of canton flannel which may be attached to the skin with glue.

Powder the resin, then add half the alcohol, then the Venice turpentine and benzine, washing the mixture into the bottle with the remaining alcohol. This glue may be removed with alcohol or ether. The bottle containing the glue should be kept tightly stoppered else the proportions of the constituents may change, and the glue become irritating to the skin. This glue does not require heating before use, and should not be applied too thickly.

Sinclair's Glue.—The details of its preparation and mode of application are as follows:

(*a*) *Preparation of Glue.*—The glue is made according to the following formula:

Very good glue	50 parts
Water	50 parts
Glycerine or glucose or calcium chloride	4 to 6 parts
Menthol	1 part

Stand for 12 hours, then melt in a water-bath. Neutralize to litmus with sodium hydrate.

The whole preparation should be made sterile.

Only very good glue should be used, and it may be tested as follows:

Place four ounces of glue in four pounds of cold water and leave in a cool place for twelve hours. If after this period it is completely dissolved, the glue is bad. If it forms a mass coherent and gelatinous, weighing eight ounces, the glue is good: if it weighs sixteen ounces, it is very good: if twenty ounces, it is excellent.

Frequent reheating evaporates the water, which should be added from time to time.

Painting over the extension with a two per cent. solution of potassium bichromate makes the glue waterproof. This must be painted over the extension in the dark and immediately afterwards exposed to the light. Painting with ten per cent. solution of formalin also renders the glue insoluble. These points are useful when the Carrel treatment is being used for wounds near the extension.

(*b*) *Application of Glue and Gauze.*—Do not shave the skin. Wash the skin carefully with soap and hot water, which contains four drams of washing-soda to the pint, to convert the oil of the skin into soap. Dry the skin. Apply the warm glue evenly with a shaving-brush, brushing all the hairs of the limb in an upward direction. Take white gauze from a sterile package, folding it so that it is eight layers in thickness, and cut it to the desired length. Keep a tension on the gauze and bring it quickly and carefully into contact with the outer and inner surfaces of the limb. Then apply neatly a close-woven bandage. When dry, apply traction. If a heavy pull is required, it is better to wait a few hours before the full pull is applied.

The gauze extension is apt to slip when the injured limb atrophies and a new extension is required. In the case of a fracture of the femur, this is usually necessary about the tenth, twentieth and fortieth days. If the gauze extension is applied carefully, it is rare to have blistering. Instead of gauze strips it is possible in the case of the leg to apply an elastic cotton stockinet.

Skeletal Traction.— Of recent years the method of applying traction directly to the skeleton by means of metal calipers or pins has been introduced and has proved of decided benefit in certain types of fracture. Skeletal traction, as contrasted with the ordinary method of skin traction, has three great advantages:

First: The force is applied directly to the bone, where its action is most desired. There is no loss or diffusion of the force as in the case of skin traction; consequently the amount of force required is less.

Second: Its point of contact with the limb is small, and as a result the entire region of the fracture, as well as the distal segment of the limb, are left uncovered for massage and general physio-therapeutic treatment. In the case of infected compound fractures, the wide access to the wound thus gained is of capital importance.

Third: When applied directly to the distal end of the fractured bone, it permits movement of the joints not only above but also below the fracture, and thus allows treatment of the soft parts and joints to go hand-in-hand with treatment of the fracture proper.

This method has been criticized on the ground that it opens an inviting pathway for bone infection, but with due care this risk is exceedingly slight and not sufficient to counterbalance the advantages. One would expect skeletal traction to be painful, but this is not borne out by actual experience. When properly applied so that direct drag on the skin is avoided, there is no more pain than with skin traction, and patients who have had experience with both methods find it on the whole more comfortable.

Suspension.— When recumbent treatment is required, it is essential to employ suspension in order to derive the greatest advantage from the

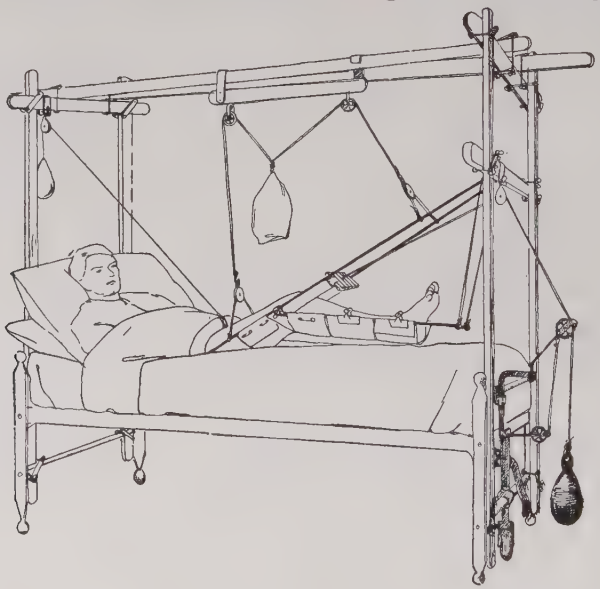


FIG. 4.—Drawing illustrating method of suspension in a Balkan frame as used in fracture of the femur. Frame shown is the demountable type used at the Massachusetts General Hospital. (Outline of Treatment of Fractures. Archives of Surgery.)

traction method. Suspension means slinging the injured limb to an overhead frame by means of a system of cords, weights, and pulleys in such a way that the weight of the injured member is exactly counterpoised and its mobility greatly increased. Suspension is of value as a physio-therapeutic measure and also in promoting the patient's comfort. With proper arrangement of the apparatus, the patient is enabled to sit, lie, or change position at will without pain or harm to the injury. (Fig. 4.) This greatly facilitates the nursing care and the resulting activity is of benefit to the general musculature and circulation. With regard to the injured part, it mobilizes joints and permits the contraction of muscles which otherwise would not be used, reduces swelling, and generally hastens the recovery of function.

Overhead Frames.— Many suitable overhead frames are now on the market, such as the Balkan frame (Fig. 5), of which there are many modifications in metal and wood, the adjustable and demountable metal frame of Morrison (see Figs. 686, 687) and the simple metal arc known as the Rainbow Frame (Fig. 6.). The one essential is an overhead support, and, if a special frame is not available, one may be readily improvised

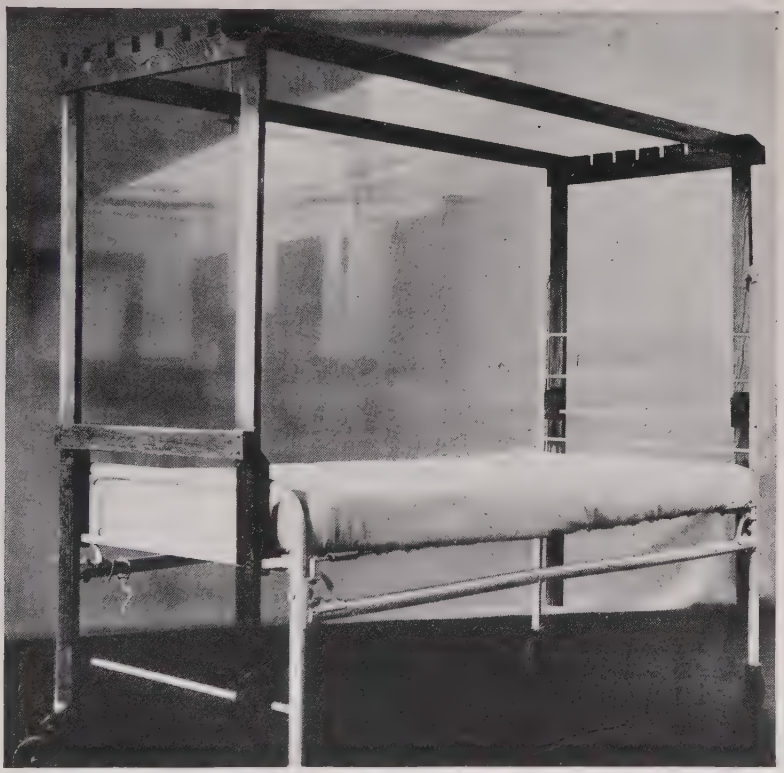


FIG. 5.—Balkan frame. Type used at Peter Bent Brigham Hospital. The end pieces are separate and hook to the bed.

by erecting wooden uprights at the head and foot of the bed to which a longitudinal beam overhead is fastened.

Indications.— The traction method of treatment is indicated in fractures of the shaft of long bones and also in articular fractures, where its advantages in allowing motion are obvious. It is used as the primary method of treatment in fractures of the femur and humerus. In other fractures, particularly those of the forearm or leg, it is employed only when other methods fail to obtain alignment. The traction method is also indicated in fractures of the metacarpal bones and phalanges when accompanied by much displacement. Lastly, it is the preferred method in nearly all cases of compound fracture.

IV. THE OPERATIVE METHOD OF TREATMENT

Operative Treatment of Fresh Fractures.— Lastly, there remains to be mentioned the method of treating fractures by open operative reduction, with or without internal fixation of the fragments. While the necessity of treating old malunited or ununited fractures by the operative method has long been recognized, the employment of the method in fresh frac-

FIG. 6.—Rainbow frame as used at the Massachusetts General Hospital. This frame is useful when a simple type of suspension is to be employed. (Outline of Treatment of Fractures. Archives of Surgery.)

tures is comparatively modern. First of the latter cases to be brought within its scope were fractures with wide separation of fragments, and in these cases operative treatment still remains the preferred method. But the great impetus to the open method was given by the introduction of the Roentgen ray, which demonstrated the general failure of conservative procedures to entirely correct deformity.

Lane [6] perfected the technic of fracture operations and introduced the method of internal fixation with steel plates. Basing his arguments on the conception that anatomic restoration of the injured bone is of paramount importance and of itself the best guarantee of good function, Lane and others advocated the more general employment of the operative

[6] W. Arbuthnot Lane, *Surg., Gyn. and Obstetrics,* April, 1909, p. 344. *Practitioner,* Nov., 1910.

method in the treatment of fresh fractures. There followed a period of enthusiastic and often ill-advised operating on fractures, and many failures and serious surgical accidents resulted before it was possible to arrive at a truer evaluation of the risks incurred and the results obtained by open procedures. Coincident with this and in part explaining the present tendency to greater conservatism, there occurred an improvement in closed methods of treatment and a wider knowledge of fractures resulting from the war. Nevertheless, the operative method has been firmly established and should be used unhesitatingly when occasion demands and circumstances permit.

Dangers.—The dangers inherent in the open treatment of fractures are several. The operation is difficult and, unless the surgeon possesses skill and experience, is likely to be time-consuming. Operations upon deep-lying bones such as the femur are apt to produce shock if not gently and rapidly executed. The risk of infection is great because of the lowered vitality of the soft tissues, the notoriously low power of resistance of bone, and the frequent necessity of employing a method of internal fixation, which leaves a foreign body in the wound. By means of able surgery and careful observance of Lane's "non-touch" technic, in combination with good hospital facilities and a well-trained operating room staff, it is possible greatly to reduce but not entirely to eliminate these risks. Bone infection results in chronic osteomyelitis and fibrous adhesions of the soft tissues with resulting functional impairment as the very least of its dangers, and the risk of more serious complications is great. Lastly, it needs to be emphasized that even with avoidance of infection, and perfect reduction of the fracture, good functional recovery is not necessarily to be expected, the trauma caused by the operation alone being sufficient in many cases to impair the result.

Before reaching a decision as to the advisability of operation in a given case, it is necessary to weigh the advantages to be gained against the risks. It is a mistake to be too quick in advising open treatment, just as it may be equally reprehensible to delay too long and allow actual malunion to occur when correction by other means is possible. In general, conservative treatment, and, in particular, efficient traction methods should be given a fair trial before resorting to operative methods.

Border-line Cases.—From the standpoint of the operative treatment, fractures may be divided into different groups. On the one hand is a small group of cases with wide separation of fragments, irreducible displacement, or with tissue interposed between the bones, in which only the open method can secure a satisfactory result. On the other hand is a group comprising the majority of all fractures, in which operative treatment is unnecessary and should under no circumstances be advised. In between is a middle group, a debatable "no-man's land," where the balance for

or against operation is tipped by the individual leanings of the surgeon. In many of these border-line cases, if competent surgery and the requisite hospital facilities are available, doubtless the open method should be employed. But, it is just in such cases that the burden of responsibility weighs most heavily since the penalty of failure is much greater than when closed methods are used.

Careful After-treatment Required.—Lastly, it should be understood that open reduction, even when combined with firm internal fixation, by no means solves the problem of after-treatment nor absolves the surgeon from the necessity of employing careful splinting methods. The operation is but one step in the treatment, and success or failure depends upon the after-care. Adequate splinting and early massage and mobilization are as indispensable for a successful result as in fractures treated by non-operative methods.

Internal Fixation.—It is not our purpose to consider here the details of the various procedures or the different methods of obtaining internal fixation, the essential features of the operations being mentioned elsewhere in connection with the individual fractures. Simplification of operative technic is greatly to be desired, and it should be the aim to dispense entirely with internal fixation and to limit the operation to open reduction alone whenever it is possible to maintain the alignment by external splinting methods. When internal fixation is required, the modern preference is for absorbable material such as beef bone, ivory, or kangaroo tendon, instead of the miscellaneous assortment of hardware at one time so generally employed. Nevertheless, in certain cases, the use of metal plates, screws, or bands is definitely indicated, but it is advisable in all such instances to remove them at a later period when union has been obtained and internal splinting no longer serves a useful purpose. The presence of such foreign bodies in contact with bone is apt to be harmful in the long run and may determine the development of a localized osteomyelitis or weaken the bone to such an extent as to result in fracture. Encircling bands interfere with nutrition and may hinder the progress of union. Removal insures the patient against difficulty at a later period and is usually a simple procedure, often possible under local anæsthesia.

Malunion.—Fractures which have healed with disabling deformity require open correction. This may consist in osteotomy with correction of alignment or division of the bone at the point of malunion, refreshening of the bone ends and reduction. In the latter case internal fixation is often necessary.

Delayed Union—The mere fact that union of a fracture is delayed is never of itself an indication for the employment of operative surgery. Delay in healing may be due to a variety of causes, and in the majority of such cases, if proper treatment is employed, union will be eventually

obtained. Among the many procedures advocated to hasten repair, none will be found more effective than measures directed towards increasing the activity of the part. Thus in the case of the arm, jointed leather and steel braces, and, in the case of the leg, caliper splints, which protect the fracture site from strain but permit active use, may be employed. Activity stimulates the circulation, counteracts bone atrophy, and promotes the formation of normal callus. At the same time, it restores the function of the muscles and joints and, if non-union finally results, operation may be performed under more favorable auspices for functional recovery than would be the case if a policy of immobilization had been followed.

Non-union.—It is impossible to determine exactly when delayed union becomes non-union. The length of time since injury is naturally important, but no arbitrary limits can be fixed for the different fractures. Failure to obtain union after exhausting the ordinary methods of treatment and after the lapse of a sufficient period of time in which to obtain healing even in the case of delayed union is the best evidence of non-union. Other evidence of value is to be obtained from the clinical and roentgenological examination. Thus, union can scarcely be expected if there is lack of approximation of the bone ends, or gross displacement, or if there has been failure to properly immobilize the fracture. Non-union may be taken for granted at a comparatively early period if the presence of any cause, either of a local or general nature, can be demonstrated.

Operative Treatment.—Non-union requires operative treatment if solid healing is to be obtained. At the same time it should be remembered that in infirm patients good fibrous union, combined with the use of a brace, is undoubtedly preferable to undertaking an operation, which the patient is unlikely to survive, or in which the chances of a successful result are small. The operation may consist in freshening the ends of the bone and placing the surfaces in close contact with each other, or it may be necessary to employ some form of bone grafting. Whatever procedure is used, an essential factor for success in all is to thoroughly open up the medullary cavity. In case of non-union, this always becomes sealed over with sclerosed bone, and unless it is widely opened, there can be no outgrowth of granulation tissue and bone-forming cells from the inside of the bone, which is an essential part of the normal process of repair.

Use of the Bone Graft.—The exact rôle of the bone graft in producing union is still undetermined, but it seems probable that while a certain number of the osteogenic cells may survive and aid in forming new bone, nevertheless, the larger part of the graft is destined to be absorbed and replaced by bone growing out from the original fragments. The chief function of a graft is, therefore, to serve as a bridge or scaffolding for the ingrowth of new osseous tissue. Of the various types of graft that

may be used, the osteo-periosteal is best for the direct stimulation of osteogenesis. Consisting of periosteum and a thin layer of bone, it contains the active cells of the cambium layer, those which are most likely to survive when nourished alone by the lymph. Active formation of new bone begins almost immediately. This form of graft does not, however, provide fixation of the fragments. When fixation is desired, a solid graft must be used. When there has been loss of bone substance resulting in a gap which must be bridged, the general preference is for a massive graft solidly fixed to the upper and lower fragments. Even such grafts may fracture or absorb in time. When simple fixation is required, but no gap exists, the sliding inlay graft may be used. In general, the modern tendency is to avoid the intra-medullary graft, which is less apt to produce union than the other types.

ROENTGENOLOGICAL EXAMINATION IN RELATION TO FRACTURES

Importance in Diagnosis and Treatment.—The roentgenological examination confirms the diagnosis of fracture made clinically and informs the surgeon as to its precise nature and the difficulties of treatment. The completeness, or otherwise, of attempts at reduction is shown by subsequent roentgenograms, and on them often depends the decision for operative treatment. Sometimes the roentgen ray provides the only means of detecting a fracture, as when it is subperiosteal or incomplete, or in the vicinity of a joint, the "sprain fracture" of the external malleolus, for example. While good roentgenograms are of the greatest assistance, a note of warning must be sounded in giving credence to the information they sometimes seem to afford, unless the surgeon is experienced in their interpretation and appreciates certain technical and anatomical facts. Many instances can be cited of fallacies and pitfalls that exist, if the evidence obtained from the roentgenogram is not weighed along with the results of clinical findings. In the case of a fracture of the shaft of the femur, if an anterior posterior view only is taken, perfect anatomical alignment may be reported in the presence of marked overriding, only visible in a lateral view. The surgeon should make it a rule to interpret the roentgenograms for himself and not depend upon the dictum of others not engaged in the actual treatment of the case, for, after all, it is the clinical and operative experience of the former that extend to the roentgenographic appearance its proper significance.

Details of Technic.—The roentgenogram is not a photograph, but rather the picture of a shadow cast by the bone, and it may, therefore, not be an accurate record of the actual state of affairs in the limb. Further, the rays emanating from the tube are not parallel and possible distortion from this cause must not be forgotten. To obtain the most accurate

record, the relative positions of the tube, object, and plate must be known and kept constant. The further the tube from the object and the nearer the object to the plate, the more nearly do the size of the object and shadow correspond; the fracture site must be centred immediately under the ray.

It should be a routine to have roentgenograms made in two planes, antero-posterior and lateral, and in difficult and doubtful cases, the sound side should be examined also. The value of stereoscopic roentgenograms in certain cases is very great, especially in deep-seated localities like the hip, shoulder, and spine. The portable roentgen machine marks a decided advance in the routine examination of bed cases, when the state of affairs as they actually exist under treatment is recorded, in contrast to the fortuitous position occupied by the fragments when the patient is removed from bed to the roentgen laboratory and the retentive apparaatus disarranged.

The importance of knowing the actual position of the limb when the roentgenogram is made is well illustrated in the case of hip injuries, where the size of the head and the length and angle of the femoral neck are all dependent upon the position of the limb when the roentgenogram is made; here again an examination of the sound side in a similar position is of value.

Knowledge of Normal Anatomy Essential.— The next essential is knowledge of normal bone and joint anatomy. Thus the normal arrangement of bony trabeculæ in different locations, and the normal changes in thickness and density of the cortex must be known, and, most important of all, a knowledge of the shape and time of appearances of the epiphyses is essential to accurate interpretations; otherwise, epiphyseal lines may be mistaken for fractures and ossifying centres for separated pieces of bone. Familiarity with the common anatomical variations is also necessary, such as the appearance of an os trigonum tarsi and the occasional presence of a double carpal scaphoid. Under the best conditions, a fracture may be overlooked even in a roentgenogram, and in deeply-seated bones it may be hard to convince oneself of the presence of a fracture.

Miscellaneous.—In the case of infected compound fracture, roentgenograms are essential for the recognition of sequestra and bone cavities; and information may be obtained as to the source of persistent sinuses and what form of operative treatment is indicated. The causes of delayed union and non-union are often discoverable by roentgenological examination, whether due to excessive loss of bony substance, to fibrous tissue intervention, or to bone atrophy, or sclerosis, and the position of the fragments and progress of such measures as bone grafting for the relief of these conditions are also shown. It should be noted that early callus

does not show in a roentgenogram, and thus union may be actually present or taking place and the appearance of fracture persist. Finally, the question of weight-bearing in fractures of the femur or tibia is usually decided by the character and abundance of the callus, the special character to be emphasized being the reappearance of normal bony trabeculæ.

SUMMARY OF TREATMENT OF FRACTURES

The following summary is quoted from the[7] "Outline of Fracture Treatment" adopted by a conference of surgeons which met at the Massachusetts General Hospital in January, 1922. It presents in outline form the chief essentials of proper fracture treatment:

I. FIRST AID

Every effort should be made to avoid any injury additional to that of the original trauma.

1. "Splint 'em where they lie!"
2. Avoid every unnecessary manipulation.
3. Transport with extreme care.
4. Treat any existing shock.

II. EXAMINATION

As complete and thorough an examination as possible should be made without causing any additional injury.

1. Begin with painless procedures.
2. Search for crepitus and abnormal mobility only when these symptoms are absolutely essential. The manipulation required to elicit these causes additional injuries.
3. Rule out, if possible, other associated injuries, especially those of nerves.
4. Elicit objective symptoms, which will be painful, only under an anæsthetic.
5. Roentgen-ray examination should be made as early as possible; roentgenograms should be taken in two planes, stereoscopic when necessary; should be of sufficient size, and should be studied with detailed care.

III. DIAGNOSIS

The simple diagnosis that a fracture exists is not sufficient. All details of pathology of the soft parts, as well as of the bone, should be considered, so as to visualize properly the problem of obtaining and maintaining reduction as well as the problem of repair and its probable duration.

[7] "Outline of Treatment of Fractures," *Archives of Surg.*, Jan., 1923.

IV. TREATMENT

Each fracture should be considered as an individual problem and the treatment directed not only to the injury of the bone but to that of the soft parts as well. The pathologic changes following a fracture interfere markedly with the ease of reduction of displaced fragments. These changes begin very soon after the injury. Infiltration of the adjacent soft parts, coagulation and later organization of the blood are the most important ones.

1. Obtaining Reduction.
   - (a) Reduction of any existing displacement should be made as soon after the injury as possible, without waiting too many hours for the roentgen-ray examination.
   - (b) Reduction should be as gentle as possible.
   - (c) Reduction should be as complete as the individual case requires.
   - (d) Reduction may be controlled by fluoroscopic examination in appropriate cases.
   - (e) Reduction should be checked by a roentgen-ray examination as soon as practical.
   - (f) Manipulation should be carried out under an anæsthetic with but few exceptions.
   - (g) Further attempts at reduction should be made as soon as the need is recognized.

2. Maintaining Reduction.
   - (a) Decide in each case the peculiar problem presented, and select apparatus accordingly, both for immediate and subsequent use.
   - (b) A decision should be reached as to how early such apparatus can be temporarily discarded to allow for massage and motion and how long it should be worn, in order to protect against further injury.
   - (c) Repair in cancellous is more rapid than in cortical bone.
   - (d) Rapidity of repair will depend very largely on the blood supply of the fragments.
   - (e) The atrophy of disuse must be borne in mind.
   - (f) The inherent value of any apparatus is of less importance than the skill with which it is used.

3. Plaster of Paris.

Circular plaster bandages are permissible only when completely divided in at least one line.

4. Massage and Movements.

If carefully and gently carried out, massage and movements can be of the greatest help. If roughly performed, they may do considerable harm. One must differentiate, under massage, between:

(a) Gentle stroking without deep pressure:
(b) Stroking with deep pressure.
(c) Kneading.

One must differentiate between:

(a) Guided active motion.
(b) Unaided active motion.
(c) Passive motion.

With these differences in mind, the various forms of each may be begun as soon as there is no danger of any additional injury or any displacement of the fragments resulting. This gentle massage and movements may cause discomfort but should never cause actual pain. The pain of forced passive movements usually means harmful stretching or tearing of soft parts, with additional necessary repair.

CHAPTER II

EMERGENCY OR PRIMARY SPLINTING OF FRACTURES

IMMEDIATE SPLINTING AND ITS BENEFITS

Dangers of Transportation without Adequate Fixation.—The importance of the immediate splinting of fractures after injury cannot be overemphasized. The majority of such injuries occur in the field, streets, or factories, and it is necessary to transport the patients over considerable distances before the place is reached where permanent treatment can be instituted. If the injured part is not effectively splinted during this journey, the grinding about of the bones with every jolt or movement causes injury to the soft parts productive of pain and shock. In the case of simple fracture there is possibility of laceration of vessels or nerves, while in compound fractures there is the added risk of disseminating through the tissues infectious material which was previously localized. At the very least the patient is subjected to severe pain, and fresh trauma is added to the original injury. It should also be remembered that muscular action is a large factor in causing displacement of fragments which may be difficult to overcome. If, immediately following the injury, relaxation of the muscles is obtained by effective splinting, deformity may be prevented before it can develop. Reduction and the securing of proper alignment at a later stage are greatly facilitated in consequence.

A good example of the benefits of immediate and effective primary splinting was furnished during the war by the case of compound fractures of the femur. In 1915, the primary mortality from such cases in the front-line hospitals was about 50 per cent. Under the system then in vogue for the evacuation of the wounded from the field only crude or improvised splinting methods were used. Many of these patients died from shock or hemorrhage during the first stage of their journey rearward, and of the remainder, so many reached the hospitals in a state of shock that in only a few was it possible to carry out the operative cleansing of the wound early enough to rid it of infection. Severe infection was the rule, and gas gangrene exceedingly common. Many surgeons seriously advised that all cases of compound fracture of the femur be treated by immediate amputation.

While not all of these poor results could be ascribed to the lack of proper splinting methods at the front, nevertheless, a remarkable improvement occurred with the introduction and general utilization of the Thomas

splint. In the British Army during one engagement, the mortality from fracture of the femur was reduced to 15.6 per cent., a reduction of nearly 35 per cent., and the number of cases whose general condition was too poor to permit immediate operation was only about 5 per cent. With the improvement in operability, there was a corresponding reduction in the number and severity of the cases of infection. In consequence, the after-treatment was greatly simplified and the late results greatly improved.

STANDARDIZATION OF SPLINTS AND METHODS FOR EMERGENCY USE

The Army Transport Splints.—Following the American participation in the World War, one of the first steps taken by those concerned with the care of the bone and joint casualties was the standardization of splints for use in the transportation of the wounded. This was done in the interest of simplification and efficiency. It was necessary to manufacture large numbers of splints as rapidly as possible and to secure their wide distribution among the units in the field. In order that they might be applied as soon as possible after injury, it was necessary that their number be few, that they be adapted to a large number of different types of fracture and different sizes of patient, and above all that they should be simple and easy of application.

The splints finally selected were seven in number and all through the war they successfully met all requirements. The enlisted personnel of the Medical Corps was thoroughly instructed in their use, fractures were splinted on the field where the injury was received, and the results achieved were excellent.

Standardization of Splints for Civilian Use.—In the accidents of civil life and peace time, standardization of splints and methods of emergency splinting is as desirable as in the casualties of war. Only by this means is it possible to obtain the immediate and efficient splinting of fractures at the time of injury. In the majority of instances first-aid treatment is rendered by laymen rather than by physicians. A supply of standard splints should be kept on hand in all factories and other centres of industrial activity where accidents are of frequent occurrence. Certain individuals should be designated to render emergency treatment and instructed in the use of the splints. Ambulances should carry them, and the drivers should be trained to apply them. Physicians who are likely to be called to treat such cases should keep at least one example of each designated splint and should carry the one indicated when responding to accident calls.

The requirements are practically the same in peace time as in war. Such splints must be cheap, of little bulk, and must be adaptable to a large variety of fractures and patients of different size. They must

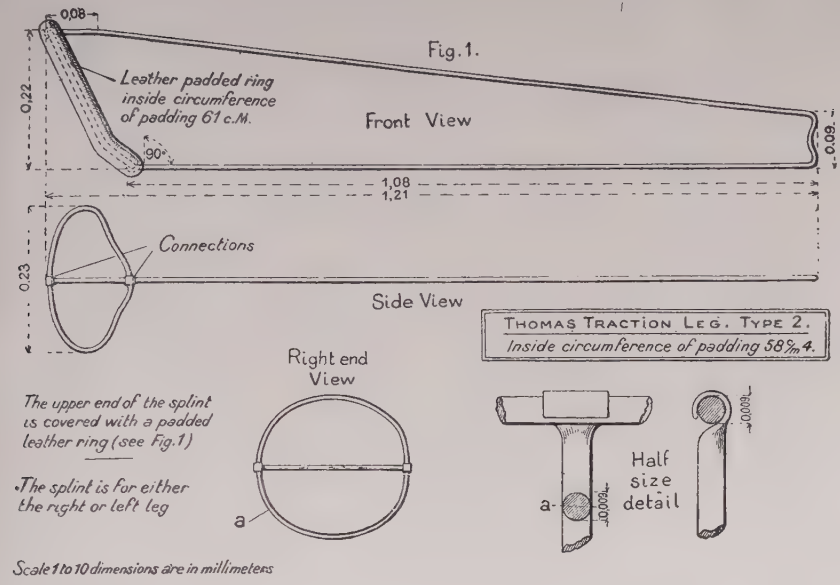


FIG 7.—Mechanical drawing of Thomas traction leg splint. (U. S. Army Splint Manual.)

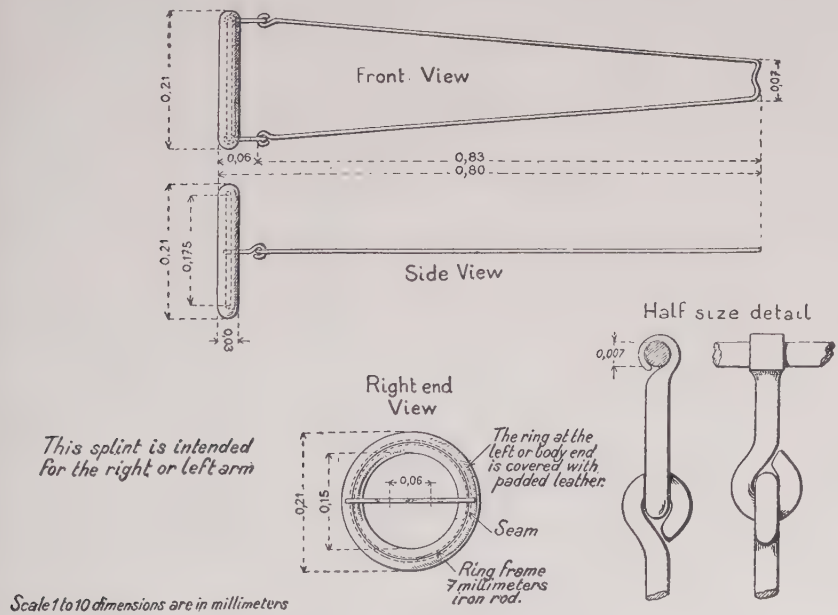


FIG. 8.—Hinged traction arm splint, mechanical drawing. (U. S. Army Splint Manual.)

combine ease of application with efficiency in performing their tasks of securing alignment and providing immobilization. The war experience has shown that splints embodying the principle of integral traction most

nearly meet all of these requirements. Traction brings about muscular relaxation and thus inhibits involuntary contraction, which is the cause of pain and displacement. It secures alignment by a pull in the direction of the normal axis of the limb and of itself provides immobilization. For

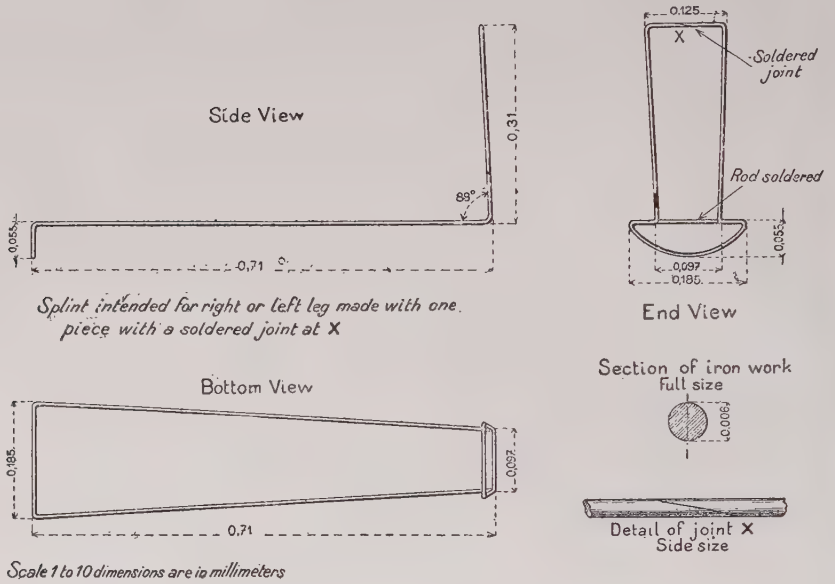


FIG. 9.—Mechanical drawing of Cabot posterior wire splint. Before using, the splint is converted into a gutter by the application of bandage. (U. S. Army Splint Manual.)

purposes of transportation, traction must be integral, that is, the splint must provide a point for traction and another for counter-traction. The latter is usually a bony prominence or muscular fold, against which one

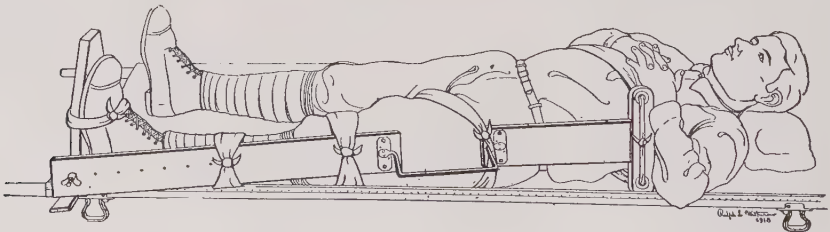


FIG. 10.—Method of applying long Liston splint in the field. (U. S. Army Splint Manual.)

end of the splint rests while the other is the end of the splint itself to which the traction bands are fixed.

Adaptation of Army Transport Splints.—The army transport splints may be adopted in whole or in part for this purpose. The Thomas leg splint (Fig. 7) and the Thomas arm splint with the hinged ring, as modified by Murray (Fig. 8), are the two splints with the greatest range of usefulness. Together they will take care of practically all

fractures of the leg or arm with the exception of injuries of the wrist, hand, or foot, in which traction cannot be used. The Cabot posterior wire splint (Fig. 9) is available for injuries of the foot and ankle, and wooden splints can almost always be improvised for fractures of the hand and wrist. The long Liston splint (see Fig. 10) is only useful in rare and exceptional cases, in injuries in the region of the hip joint with a wound so situated on the outer and posterior aspects of the hip that the usual Thomas splint cannot be applied. The Bradford frame

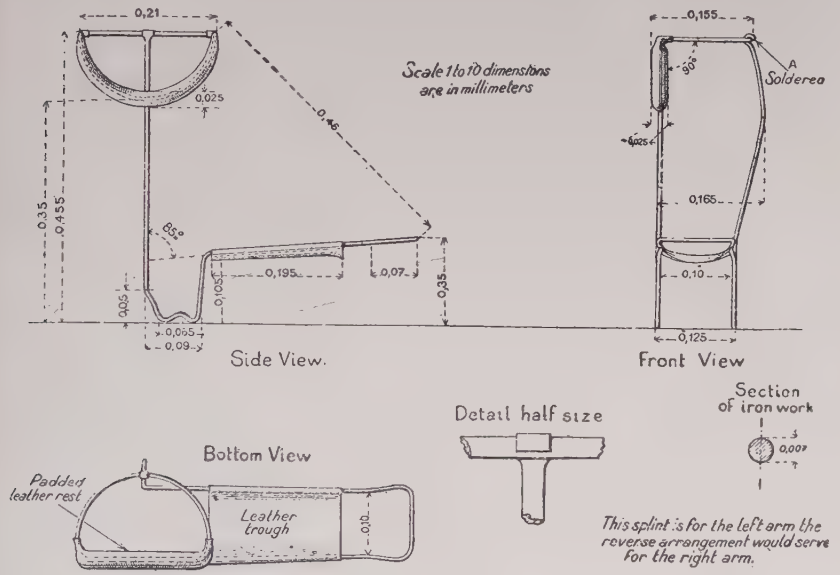


FIG. 11.—Mechanical drawing of Jones humerus traction splint. (U. S. Army Splint Manual.)

(see Figs. 461, 462) is useful in case of fracture of the spine or pelvis, but for purposes of transportation a stretcher, particularly of the snow-shoe litter type (see Fig. 20), serves equally well. The Jones humerus traction splint (Figs. 11 and 12) offers a valuable and comfortable means of splinting fractures of the humerus or forearm when the patient can walk. It has not as wide a range of usefulness, however, as the modified Thomas arm splint. The above list of splints is none too large to meet the requirements of the varied injuries encountered in time of war, but in time of peace a little more may be left to chance and it is possible to take care of all the more serious forms of injury by the provision of the following splints:

1–Thomas leg splint
1–Thomas arm splint (Murray's hinged modification)
1–Cabot posterior wire splint
1–Stretcher

METHODS OF APPLYING SPLINTS FOR EMERGENCY USE

1. Thomas Arm Splint (Hinged Type)

Indications.—Any skeletal injury involving the bones of the forearm, the elbow, the humerus, or shoulder.

Method of Application.—The arm is exposed by removing or cutting away the clothing to the shoulder. Adhesive traction strips of the length of the arm are prepared and the ends fixed to pieces of cord or bandage (see Fig. 2). The strips are then applied to opposite skin surfaces of the arm and fixed by circular turns of a bandage. The ring is then threaded over the arm and pushed up against the side of the chest, and the ends of the traction strips are tied to the end of the splint, additional tension being obtained by twisting the cords with a stick. The arm is supported in the splint by slings of bandage pinned to the cross-bars (Figs. 13, 14). When the splint is in place, the arm may be adducted to the side.

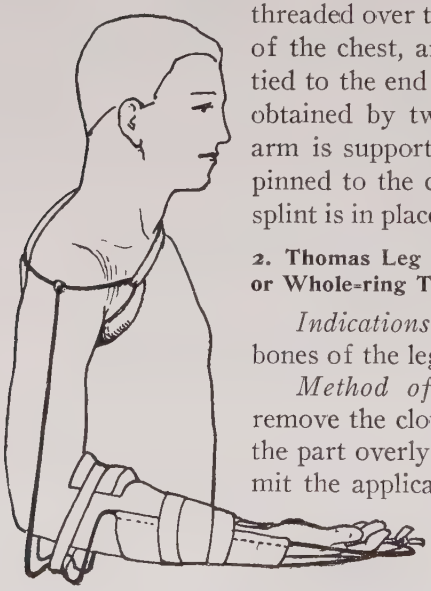


FIG. 12.—Method of applying Jones humerus traction splint for emergency use. (Outline of Treatment of Fractures. Archives of Surgery.)

2. Thomas Leg Splint (Either of the Half-ring (Fig. 15) or Whole-ring Type (See Fig. 7))

Indications.—Any skeletal injury involving the bones of the leg, the knee, the femur, or hip.

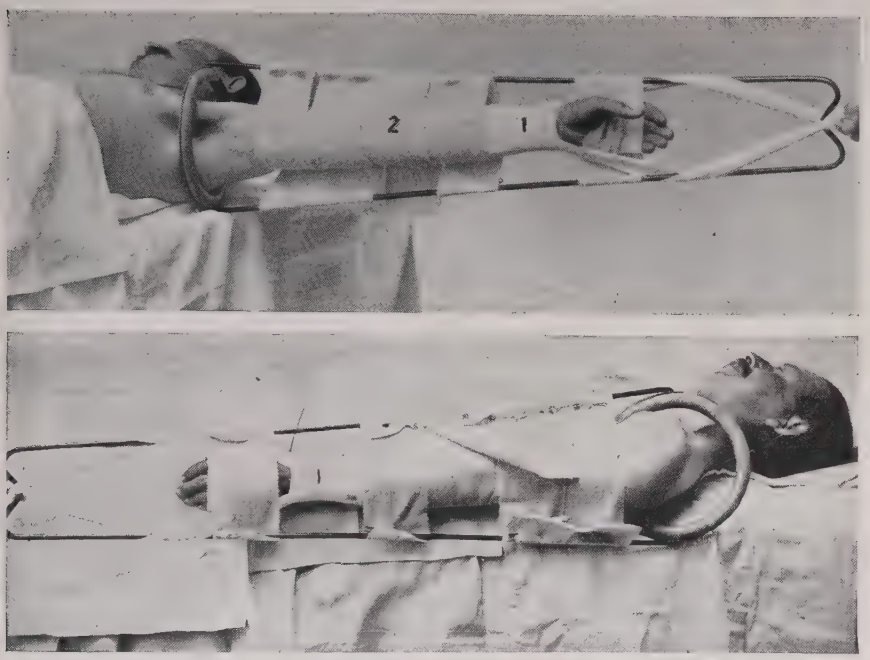
Method of Application.—It is unnecessary to remove the clothing except in case of a wound when the part overlying the latter may be cut away to permit the application of a dressing. The boot should be left in place for the purpose of securing traction. This may be obtained by the application of a clove-hitch of bandage to the ankle (Fig. 16) or by passing a long nail through the heel of the shoe (Figs. 17, 18). The ring of the splint is passed over the leg and pushed up against the tuberosity of the ischium, and the traction is obtained by tying the extension cords to the opposite end and twisting them with a stick. The limb is supported by turns of bandage fastened to the side bars of the splint which convert it into a trough or gutter. The wire foot support is attached to the splint (Fig. 19), holding the foot in right-angle flexion, the latter being fixed with a figure-of-eight turn of bandage. The end of the splint is fastened to the stretcher bar to hold it solidly in place.

3. Cabot Posterior Wire Splint

Indications.—Injuries of the foot and ankle.

Method of Application.—It is unnecessary to expose the part by removal of the clothing unless there is a wound which requires dressing.

The splint is prepared by covering the skeletal wire frame with bandage (see Figs. 777, 778, 779). This should be padded with cotton or, in case this is lacking, a folded garment may be used. The padding should be arranged to leave a space under the heel in order to avoid pressure. The limb should be placed in the splint with the foot resting against the foot piece and secured with strips of adhesive plaster and a circular band-



FIGS. 13 and 14.—Application of the hinged traction arm splint. (13) Fracture of lower third of humerus, showing (1) extension strips applied, and (2) method of slinging arm to the upper bar of the splint. (14) Same as figure 13, showing arm brought to the side in position for transportation. (Jones' Orthopædic Surgery of Injuries.)

age. Additional fixation may be obtained by the application of pieces of splint board to the sides of the limb (see Figs. 780, 781).

4. Hand and Wrist Splint

Indications.—Injuries of the wrist and hand.

Method of Application.—Splint board or other wooden material of similar size may be improvised for the fixation of the wrist and hand, plentiful padding being essential, and fixation being secured by adhesive strapping and bandage. A triangular sling provides additional support.

5. Long Liston Splint

Indications.—Extensive injuries of the region of the hip.

Method of Application.—The splint is applied to the side of the body over the clothing and secured by turns of bandage encircling the trunk

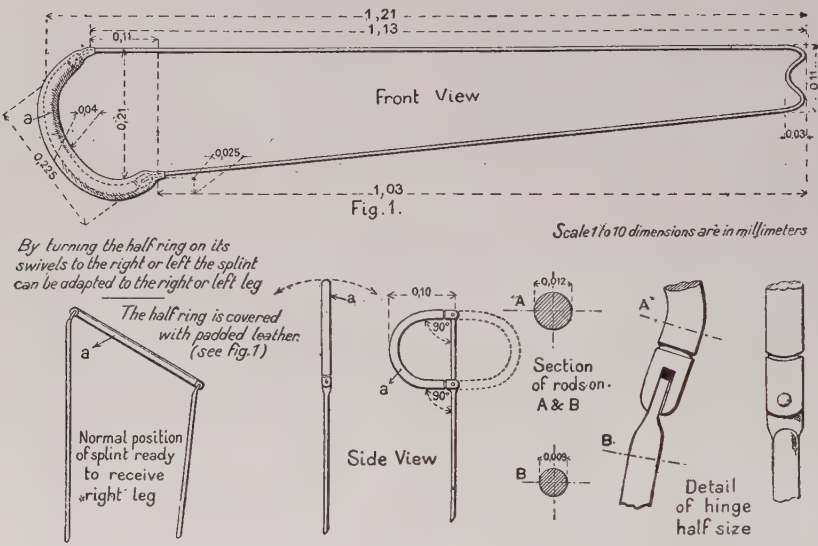


FIG. 15.—Mechanical drawing of hinged half ring traction leg splint. (Blake Keller.) (U. S. Army Splint Manual.)

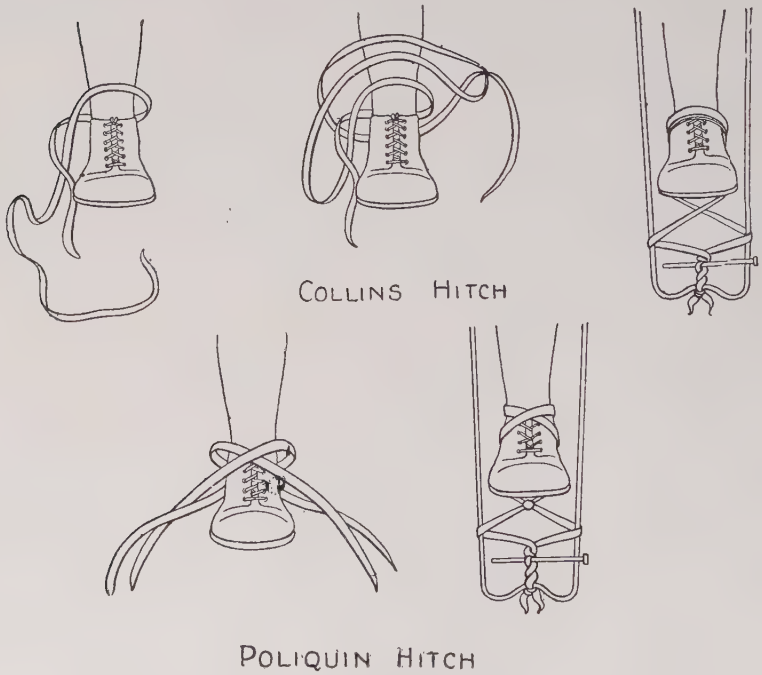
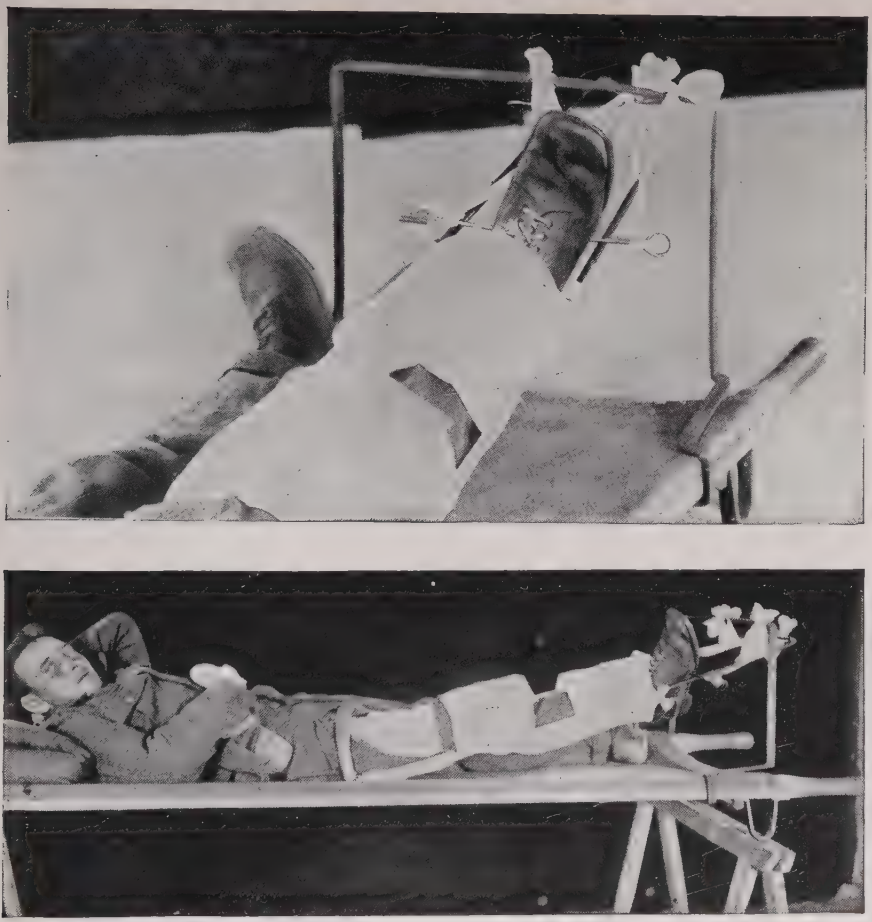


FIG. 16.—Emergency method of fixing bandage to the ankle to obtain extension when applying a traction leg splint in the field. (U. S. Army Splint Manual.)

as well as the limb (Fig. 10). Traction may be obtained by means of a clove-hitch about the ankle which is fixed to the foot piece, counter-traction being provided by a padded perineal band, which is fastened to the upper end of the splint.



FIGS. 17 and 18.—Method of applying Thomas traction leg splint for emergency use. (17) In this case, traction is being obtained by means of an iron pin or nail passed through the heel of the boot. (18) Same, lateral view. (Jones' Orthopædic Surgery of Injuries.)

6. Bradford Frame, Snow-shoe Litter, etc.

Indications.—Fractures of the spine or pelvis.

Method of Application.—The chief requirement in this class of injuries is a firm surface upon which the body may be lifted or transported. The Snow-shoe litter (Fig. 20) was ideal for this purpose during the war as the patient could be bound to it so firmly that narrow turns in the trenches could be readily negotiated by turning the frame on its

side. A Bradford frame (see Fig. 461) or ordinary stretcher serves nearly as well in ordinary traumatic cases.

7. Pillow and Side Splints

This is not included among the army transport splints, but it is an

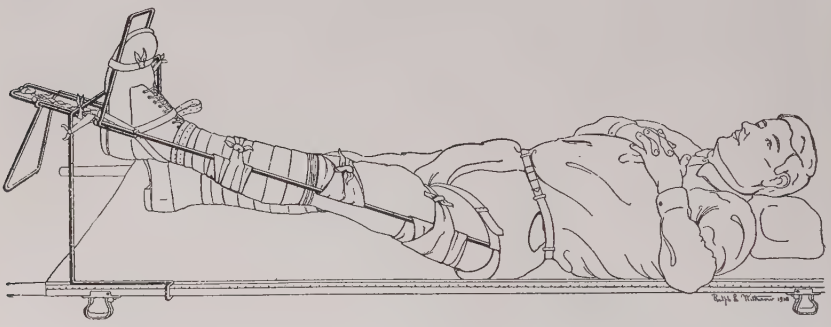


FIG. 19.—Method of applying hinged half ring leg splint in the field. (U. S. Army Splint Manual.)

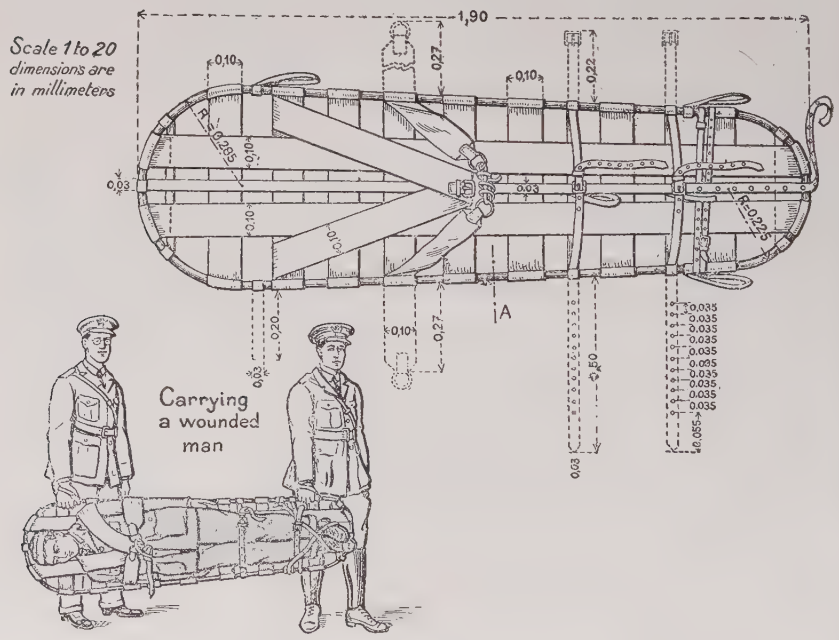


FIG. 20.—Snow-shoe litter. (U. S. Army Splint Manual.)

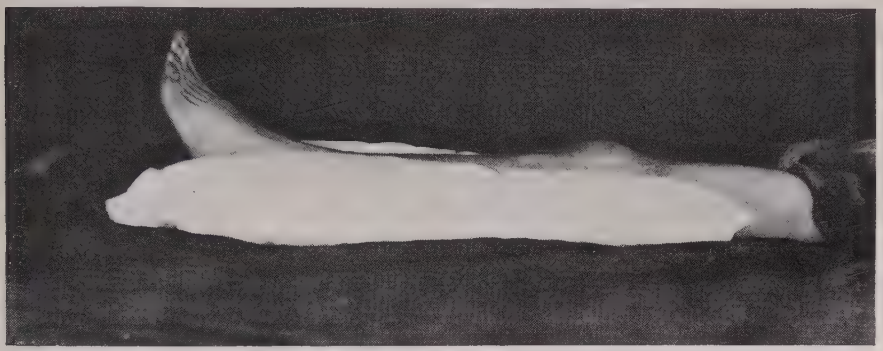
old time-honored method of emergency splinting and serves its purpose admirably.

Indications.—Injuries of the foot, ankle, and lower leg.

Method of Application.—A pillow is placed under the limb and its sides folded up and secured to each other with safety pins in such a way

as to envelope the leg. Pieces of splint board are applied to the sides and back of the leg and fixed with buckle straps or circular turns of bandage. The ends of the pillow below the foot are folded across the latter and pinned, holding the latter in right-angle flexion (Fig. 21).

A



B

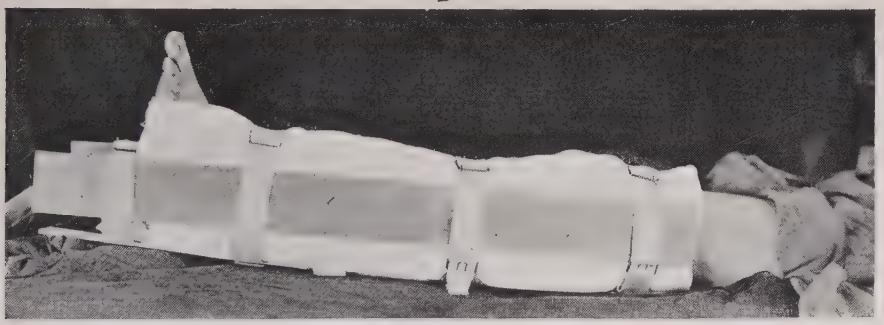


FIG. 21 (A, B).—Pillow splint. (A) Depression is made lengthwise in a pillow, and the leg placed upon it. (B) The edges of the pillow are pinned together over the leg, the ends being fastened across the bottom of the foot. Three pieces of splint board are applied as shown and fixed with buckle straps.

CHAPTER III

COMPOUND FRACTURES AND DISLOCATIONS

GENERAL CONSIDERATIONS

Relation to Infection.—The subject of compound injuries derives its special importance from its relation to the subject of wound infection. A fracture or dislocation is compound when there is an open wound leading down to the seat of bone or joint injury. This not only provides a portal for the entry of infection, but in most instances the nature of the trauma and the manner in which the injury is produced are such as to cause contamination with the worst type of infective material.

The Consequences of Infection.—Infection of a fracture is a serious matter not only because bone offers but slight resistance to the invasion of bacteria, and thus favors an extension of the septic process and the development of some of its most serious complications, but also because bacteria, when they have once entered bone, are extremely difficult to get rid of, and chronic osteomyelitis sometimes lasting for years may be expected as the very least result. Also, the necessity of treating the infection interferes considerably with the treatment of the fracture and still further darkens the prospect of obtaining a good functional result. Wide exposure of the part and easy access to the wound are essential for the former, but may be difficult to secure except at the cost of improper reduction and alignment and inadequate immobilization. Shortening, angulation and bony deformity with serious disturbance of function have frequently resulted from this cause.

The Problems of Treatment.—The treatment of compound fractures, therefore, presents two problems; the first relates to the prevention and treatment of infection, and the second to the reduction and splinting of the fracture under the special conditions created by the presence of a potentially infected wound. While for purposes of discussion it is convenient to consider these parts of the treatment separately, it should always be remembered that this is an arbitrary division, and that in reality the two are closely related. Thus, if the treatment of the wound is successful in preventing the development of infection and primary wound healing results, the compound fracture is converted into a simple fracture and the splinting problem is, therefore, greatly simplified. On the other hand, if the treatment is directed primarily toward the wound in an effort to prevent or suppress infection and neglects the fracture, the result is likely to be disastrous. Nothing is more certain than that improper splinting and imperfect fixation favor the development and continuance of wound infection.

WOUND INFECTION IN GENERAL

Factors Which Determine Infection.— The war experience has considerably modified our views concerning the mechanism of wound infection. Formerly, it was considered that the implantation of pathogenic bacteria was almost the only essential, but now the importance of other influences is also generally recognized. Whether infection is or is not to develop is determined chiefly by the interaction of the three following factors:

1. The number, character, and virulence of the infecting organisms.
2. The conditions present locally in the wound and the vitality of the infected tissues.
3. The general state of the body resistance.

Character and Virulence of Different Organisms.—The bacteria which may cause wound infection are legion. While the ordinary pyogenic cocci play the predominant rôle, they are seldom found in pure culture, and in traumatic injuries mixed infections are the rule. The virulence of different strains of cocci varies within wide limits. The streptococcus hæmolyticus is noted for extraordinary virulence and when present in a wound is almost certain to overcome, at least temporarily, the local defenses of the body. Anaërobic infection is particularly serious, and included among the pathogenic organisms of this class are the various bacilli which may produce gas gangrene, of which the Bacillus Welchii is the best known example, and, in addition, the Bacillus Tetanus. Their habitat is soil which has been cultivated with manure, and it is only by direct contamination with earth or by the in-carrying of soiled fragments of clothing that they gain entry to a wound. The gas bacilli of themselves possess low virulence and can thrive only in tissues which are deprived of proper blood supply. They show a special predilection for devitalized muscle tissue, and it is there that they first take root and develop. The bacillus of tetanus is notorious for its extreme latency, and its spores may persist in a wound for many months and be awakened into activity by secondary operations performed long periods after the original injury.

Influence of Local Conditions Within the Wound.—The conditions present locally in the wound and the vitality of the infected tissues are important factors in determining the fate of the invading organisms. When these are implanted in small amount in a simple incised wound whose walls are healthy, the tissues are able in the majority of instances to destroy them before they have had a chance to multiply. On the other hand, contused and devitalized tissues and those with impaired blood supply provide culture media for the growth of bacteria and protection against the defensive forces of the body. The presence of dirt, fragments of clothing, or other foreign bodies supplies not only the means of transplanting into the wound large quantities of pathogenic organisms, but

also furnishes shelter for their development. The vitality of the tissues is impaired by infiltration with blood, and hæmatomata of themselves provide avenues for the extension and penetration of infection. In the case of injury to the main arterial supply, the part distal to the point of injury is deprived of blood, and, if any of the organisms of gas infection are present, their rapid development may be expected.

General Body Resistance.—The importance of the state of general body resistance in preventing and overcoming infection is too well recognized to require more than mention. It bears a close relation to the general condition of health and is particularly likely to be weakened by hæmorrhage and shock and is also unfavorably influenced by exposure, general debility, and old age.

MECHANICAL STERILIZATION OF THE WOUND

Débridement and Its Results.—From what has been said concerning the mechanism of wound infection and the factors which play a part in its development, it will be seen that if a potentially infected wound is treated soon after injury by an open operation which removes all dirt and foreign bodies and excises all damaged and devitalized tissues, the development of infection may be prevented in a large number of cases. Such is the underlying principle of the operation popularly known as débridement, which, principally due to the work of Lemaitre,[1] Gray,[2] and Depage,[3] was introduced and adopted during the later years of the war as the means of preventing infection in recent cases of gun-shot injury. The operation is a delicate, painstaking dissection of all the contaminated and damaged tissue and necessitates complete exposure and careful exploration of all parts of the wound. The technic is elaborate and is described elsewhere (page 53) in greater detail, particularly as it relates to compound fractures. By this means not only are the great majority of the infecting organisms removed, but the dirty, irregular, traumatic wound is transformed into a clean, healthy, surgical wound, and the conditions of combat between host and invaders are completely altered. The war experience has shown that when wounds are treated in this manner within a short time after injury not only does suppuration fail to develop, but primary healing may be obtained in the great majority of cases. In the traumatic injuries of peace time, débridement gives even better results than in time of war, since proper facilities are closer at hand and the patient can usually be treated with less delay.

The Factor of Time.—The time element is a most important factor. Immediately after injury, if the conditions are favorable, the implanted

[1] René Lemaitre, *Chirurgie Réparatrice et Orthopédique*, Vol. 1, *Masson et Cie*, Paris, 1920.

[2] H. M. W. Gray, *New York Med. Journ.*, March 23, 1918.

[3] Depage, *Annals of Surgery*, 1919, p. 575.

bacteria begin to multiply, but the growth is at first confined to the surface of the wound and to the bits of necrotic tissue lining the walls. During the first twelve hours there is very little penetration of the surrounding tissues, and if the operation is performed during this period, the chances are good for almost complete sterilization of the wound. During the second twelve hours considerable invasion of the surrounding tissues takes place, but not to such an extent as to greatly diminish the good results of débridement. During the second twenty-four-hour period infection is well under way, but, nevertheless, the operative removal of contaminated and damaged tissues will in some cases prevent infection, and in the majority at least, minimize it. After forty-eight hours infection is well established, and the preventive operation is no longer indicated; instead the wound should be widely opened, foreign bodies removed, ample drainage provided, and arrangements made to treat the infection, preferably by the Carrel-Dakin method.

CLOSURE OF THE WOUND BY PRIMARY, DELAYED PRIMARY, OR SECONDARY SUTURE

It is important to close the wound as early as may be possible without risk to the patient; and depending upon the circumstances surrounding the injury and the local conditions within the wound, this may be done either by the method of Primary Suture, Delayed Primary Suture, or Secondary Suture.

Closure by Primary Suture.— By Primary Suture is meant the method of closing the wound by suture as the final step in the operation of débridement. Usually this technic should be followed only in the case of wounds without great depth which are seen within twelve hours of injury and in which the surgeon feels absolutely convinced that he has succeeded by operation in mechanically sterilizing the wound. During the war primary closure was successful in 80 per cent. of the cases, but these were chiefly soft-part injuries not involving bone. In compound fracture the dangers are greater, as it is not always possible to be sure that organisms are not concealed in some minute fissure of the bone where it is impossible to reach them. In compound dislocations or intra-articular fractures primary closure of the wound should be the method of choice, as the synovial membrane, like the peritoneum, has great power of resisting infection, and the conditions of combat are more favorable to the host when the joint is closed rather than open; also by this method there is much greater chance of recovery of function. In all instances the wound should be cultured prior to closure and if the presence of streptococcus hæmolyticus is demonstrated or the number of bacteria is excessive, the wound should be re-opened. The presence of gas bacilli is not of itself an indication for re-opening the wound as its virulence is slight and it does not develop in a healthy wound.

Closure by Delayed Primary Suture.— The method of Delayed Primary Suture consists of leaving the wound open at the end of débridement, packing it with sterile gauze which may have been wrung out in some non-irritating antiseptic solution, and awaiting developments. If, at the end of 3 or 4 days, the surface has a healthy appearance and cultures are negative for streptococcus hæmolyticus, the wound may be closed by widely interrupted suture of its skin margins. In some cases skin sutures may be inserted at the time of the original operation, and tied only at the end of several days. Delayed Primary Suture is safer in cases of compound fracture than Primary Suture as practically nothing is lost in the time of healing, and the delay allows any serious infection to manifest its presence at a time when the wound is wide open and ample drainage is provided. If the appearance of the wound is not one to justify closure at the end of 3 to 5 days, this procedure should be abandoned and the Carrel-Dakin method of treatment applied, with the hope of being able to disinfect the wound and close it by secondary suture.

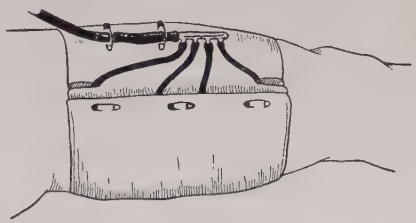
Closure by Secondary Suture.—Secondary Suture is the method of dealing with long-standing wounds which by one means or another have been rendered comparitively sterile so that closure is possible without undue risk. The method is classically employed in connection with the Carrel-Dakin method of wound sterilization, but long prior to this it had been employed with good results from time to time in the case of small granulating wounds. Nevertheless, the procedure is attended by great risk unless carried out under careful bacteriological control, and certainly the most striking and brilliant results with the smallest percentage of failures have been achieved by the minute observance of Carrel's technic. Secondary closure greatly shortens the time of healing and substitutes a soft, non-adherent surgical scar for the large, irregular cicatrix which results from a granulating wound and which often limits function.

THE CARREL-DAKIN METHOD OF TREATING INFECTED WOUNDS

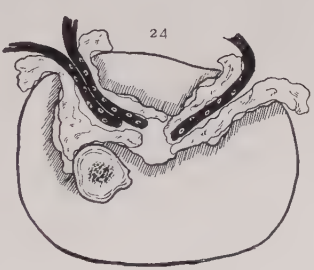
General Considerations.— The Carrel-Dakin method is undoubtedly the best at our command for treating infection when it has once become established. Introduced in 1915 following a careful investigation by its originators, after whom it is named, of the entire subject of wound infection and the action of antiseptics, its value was quickly and definitely established by surgeons of the rank of Tuffier, Depage, Chutro, and many others who were willing and able to carry out all its technical details with meticulous care. The subject is too large and the need for precise information too great to permit its description in brief. Surgeons who are unfamiliar with the method should read the small volume, " The Treatment of Infected Wounds," by Carrel and Dehelly (Hoeber, New York City, 1919).

Special Features.—The method constitutes in reality an entire system of treatment with a carefully detailed plan of campaign, which must be carried out flawlessly from beginning to end if success is to be obtained. It begins with the accurate preparation of the solution, which is practically isotonic with blood serum and contains 0.35 to 0.50 per cent. of hypochlorite of soda, with small quantities of neutral soda salts and no

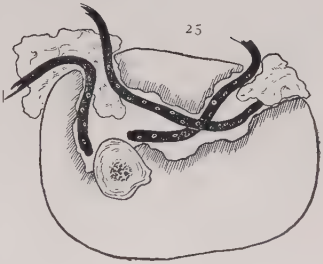
22



23



24



25

Fig. 22.—Flask, conductor tube, glass distributing arm with four irrigating tubes attached as used in the Carrel-Dakin method of wound sterilization. (After Carrel and Dehelly.)

Fig. 23.—Carrel-Dakin method of wound sterilization. Arrangement of dressing with distributing tubes attached. (After Carrel and Dehelly.)

Fig. 24.—Incorrect arrangement of irrigating tubes in wound. (After Carrel and Dehelly.)

Fig. 25.—Correct arrangement of tubes in wound. Direct contact of the solution with the wound surface is assured. (After Carrel and Dehelly.)

free alkali. The ordinary pharmaceutical preparations made from tablets are irritating and of little value. The wound must be prepared by operation, the depths being laid open, the pockets explored, and all foreign bodies removed, including entirely loose fragments of bone. Irrigating tubes of the proper type and number must then be selected and inserted in such a manner as to insure contact between the solution and all parts of the wound surface. A large absorbent dressing is next applied and the tubes connected with the distributing system which leads from the reservoir, the latter being placed at the proper level to insure a free flow of the solution and yet not so high as to cause excessive pressure in the wound. In order to maintain the proper concentration of the antiseptic in the wound, it is necessary to instil the solution regularly at two hourly inter-

vals, a quantity of 10–20 c.c. usually being sufficient. The dressings should be changed every day with scrupulous aseptic technic, instruments being used in the handling of all materials. The skin edges should be cleansed with neutral sodium oleate and protected with strips of gauze impregnated with sterile vaseline.

Bacteriological Control.—The progress of disinfection should be controlled every two to three days by routine bacteriological examination of smears made from different parts of the wound and count of the number of organisms per microscopic field. These should progressively diminish in number, and if this fails to take place, it is a sure sign of error in technic or reinfection of the wound from some bacterial *nidus* which is not being reached by the solution. In each instance the cause of delay should be traced down and located, and the remedy applied which is appropriate to the particular case. When the count has decreased to one organism in twenty microscopic fields or less and when the cultures demonstrate the absence of streptococcus hæmolyticus, closure of the wound by secondary suture is indicated and in the majority of cases will be attended by success.

Necessity of Careful Observance of Details.—All these points and many others of equal importance but not named should be emphasized, as their observance is an integral part of the Carrel-Dakin plan of treatment. Many surgeons have employed the method in abbreviated form and then reported their failure to obtain results by what they considered to be a careful observance of the Carrel-Dakin technic. Indeed, there is great danger that it may be brought into disrepute by this tendency. We do not believe that a single surgeon who has been properly trained in the method and who has had a chance to carry it out in any considerable number of cases can have failed to be convinced of its effectiveness. Unfortunately, a chain is no stronger than its weakest link, and perhaps it is the fault of this method to be too complicated and to require too much time to fit into the rush of clinical work. However, it should be noted that there was great rush and pressure in the care of the wounded during the war and that it was precisely under these conditions that the method was developed and became established.

Special Features Relating to Compound Fractures.—Certain points in reference to the application of the technic in compound fractures deserve to be emphasized. It is of fundamental importance to bring the solution into contact with all parts of the wound, but in compound fractures the organisms after a little time penetrate the bone, entering through fissures and particularly settling down in fragments which have lost their blood supply. In this situation they are sheltered from contact with the solution and from the leucocytes coming from the soft parts, and sterilization is not possible unless the sequestra are first removed, leaving a fresh sur-

face of living bone on all sides, which resists bacterial invasion. This explains the tenacity of infection in compound fractures and the futility of attempting to obtain chemical sterilization of the wound unless there is previous thorough preparation of its depths and removal of all foreign bodies including dead fragments of bone.

When Indicated.—The Carrel-Dakin method should be employed in all cases of infected compound fractures. It is also of great value as an immediate sequel to the operation of débridement in recent cases when, either on account of the lapse of too much time, or the impossibility of removing every bit of damaged and infected tissue, or because of the nature of the wound contamination, or the fear of poor blood supply, the development of infection is expected. In fact, the authors recommend its use in every case of compound fracture in which the wound is not closed by primary suture. The earlier it is applied, the sooner is the stage of surgical sterility reached and the more quickly is the closure of the wound possible.

B. I. P. PASTE

General Considerations.—Rutherford Morrison in 1916 advocated the use of a paste composed of bismuth, iodoform, and paraffin as a means of treating infected or potentially infected wounds following an operation to obtain mechanical cleansing. A paste of nearly similar constitution had been previously used for many years by Stiles in the treatment of chronic infected sinuses. Under the popular name of Bipp it was taken up and its use quickly became general among the surgeons of the British Army.

The paste is made as follows:

Bismuth subnitrate	℥viii
Iodoform	℥xvi
Liquid paraffin	℥viii

The powders should first be mixed together in a mortar and then the paraffin incorporated, a sufficient quantity being used to form a paste. With a spatula, this should then be carefully rubbed down in small quantities at a time on a slab.

Use of the Paste.—Following débridement, the paste is applied in small quantities to the wound surfaces and rubbed into the tissue, the excess being removed with a gauze sponge. The latter detail is very important, as many cases of bismuth poisoning have resulted from its use in excessive amount. The paste should form a thin coating over the entire wound surface.

[4] Rutherford Morrison, *The Bipp Treatment of War Wounds*, Oxford War Primer, 1918.

Mechanical Action of the Paste.— The value of the paste lies not so much in its antiseptic action, which is decidedly weak, but rather in its mechanical effect in retarding the process of healing and providing drainage. When a wound which has been treated in this manner is closed, the paste interferes with the outgrowth of the capillary loops and delays the cohesion of the surfaces for a considerable period. Even as late as five to seven days after closure the sutures may be removed and the flaps separated without hæmorrhage or any other evidence of laceration of tissue. If the wound is closed with widely interrupted sutures, perfect drainage is provided, and pocketing in case of infection is prevented.

Results Obtained.—The paste has been employed at the Royal Infirmary in Edinburgh in a large series of recent compound fractures as a sequel to the operation of débridement and preliminary to closure by primary suture, and from this experience one of the authors feels convinced that it has been possible to immediately close a larger percentage of the wounds than would have been safe if it had not been used. Even when infection develops, the failure is only partial instead of complete, as healing of the major part of the wound is obtained and only a small sinus remains. The authors do not recommend the use of the paste in wounds which are to be left open, nor in infected wounds as a substitute for the Carrel-Dakin method of the treatment, and when it is used in connection with the primary closure of wounds, it should be done with a realization of the infinitely greater importance of thorough and painstaking débridement.

LATENT INFECTION IN HEALED COMPOUND FRACTURES

Danger of Reinfection in Old Wounds.—The mere fact that an infected wound has healed and remained healed for many months is not an indication that infection may not lurk in its depths. During the process of repair a stage is frequently reached in which a kind of auto-immunization is established which allows healing to proceed in spite of the presence of pathogenic bacteria. Some of the organisms are reduced to a dormant state and become encysted in the tissues. They may persist in the cicatrix for months or even years and are awakened to new life by operative interference or trauma. This is particularly true of compound fractures, and the surgeon must be warned against undertaking secondary operative procedures for the insertion of bone grafts or the correction of bony deformity in such cases until the lapse of at least six months or a year from the time of complete healing.

Special Precautions to be Used in Secondary Operations.— Even then special precautions are necessary if disaster is to be avoided. Daily massage of the scar for a period of a week before operation is a useful test, as it is apt to stir up infection, if present, and this is indicated by pain and redness in the region of the wound. Excision of the scar in both its super-

ficial and deep portions is an important part of the procedure and one likely to get rid of injurious organisms, if present, at the same time leaving clean, healthy wound surfaces to deal with any that may remain. If any doubt exists concerning the safety of operation, it is advisable to perform this in two stages. At the first the scar is excised and if a bone graft is to be inserted, its bed is prepared. The wound is then closed and developments awaited. If infection develops, no great harm has been done, whereas, if the wound remains clean, the second stage of the operation may be performed at the end of a week and the graft inserted or the malunion corrected with the assurance that clean healing may be expected. The effect of radiant heat, applied locally, is often a good indicator as to the presence or absence of latent sepsis. When present a reactive inflammation is set up.

DIFFERENT TYPES OF COMPOUND INJURIES

Infected and Uninfected Cases.— Not all compound injuries are alike, and it should not be understood from what has been said concerning wound infection that all cases are destined to develop that complication. It has long been recognized that in a large number of cases, even with conservative treatment, suppuration does not develop and uneventful healing occurs. The chief essential for the differentiation of the potentially infected from the uninfected cases is an understanding of the different ways in which compound fracture may be produced and the chances for wound contamination which this involves.

Compound injuries may be the result of external or internal violence. In the former, the wound is produced by the same external agent that causes the fracture. In the latter, it is caused by violence from within, the bones being displaced so forcibly that the overlying tissues are torn or a fragment may actually be driven outward through the skin.

I. COMPOUND INJURIES IN WHICH THE WOUND IS PRODUCED BY EXTERNAL VIOLENCE

Mechanism of Injury in Relation to Infection.— The injury may be produced by a blow from a moving or falling object, or by a crushing force, as in a collision or run-over accident, or by a penetrating missile, such as a bullet or flying fragment of steel, or by a cutting instrument, such as a knife. In each case there is actual entry into the tissues of an infected, foreign body with the probable implantation of bacteria. If the foreign body is small, and its velocity great, as in the case of a rifle bullet, the clothing covering the point of injury is merely penetrated and pushed aside and the amount of wound contamination is negligible. If, on the other hand, the injurious agent is large, almost invariably small pieces of clothing are carried into the wound and, depending upon other circumstances, dirt may actually be ground into the wound as well. In such

cases the tissues are greatly traumatized and the blood supply of the surrounding structures may be considerably impaired, even without actual vascular injury. Conditions are, therefore, ripe for the development of severe infection in all cases of injury by this mechanism except those resulting from rifle bullets with small punctate wounds.

II. COMPOUND INJURIES IN WHICH THE WOUND IS PRODUCED BY INTERNAL VIOLENCE

Cases with Contaminated Wounds.—In this type of injury, the amount of wound contamination may be great or nil. If the end of the bone actually protrudes through the skin, it inevitably becomes soiled. In many cases this exit is only temporary and is immediately followed by its return to a deep position in the wound. This transplants infection from the surface to the deep-lying tissues and over an extensive area in direct contact with the bone. The trauma to the tissues is great, and severe infection may usually be expected. Anaërobic infection may develop if the bone is contaminated by ground soil, either from direct contact with the ground or from the soiled condition of the clothing.

Cases with Uncontaminated Wounds.—However, in a large number of injuries by this mechanism, actual protrusion of the bone does not occur, the force being only sufficient to cause rupture of the overlying skin. No contamination is carried into the wound, and the chance of subsequent infection is very slight. Such cases can usually be differentiated from those potentially infected by the small size of the wound, which is insufficient to have permitted the exit of the bone.

CLINICAL EXAMINATION OF CASES OF COMPOUND INJURY

General Considerations.—The clinical examination is of the greatest importance not only in yielding information as to the nature of the bony lesion, the extent of the damage, the presence or absence of complicating injuries, and the general condition of the patient, but also in indicating the probability of bacterial contamination of the wound. The extent and thoroughness of the examination should in all cases be governed by consideration of the patient's general condition, and the necessity of preventing further infection, and of avoiding additional trauma. Only the special features relating to compound injuries require mention.

Information Relating to the Question of Infection.—The description of the accident should first be obtained, and points to be especially noted are its time, the nature of the trauma, the mechanism of injury, whether the bone was actually seen to protrude, what local treatment was applied, and any other information obtainable bearing upon the contamination of the wound. The clothing should be inspected, and its state noted, whether torn or shredded in the region of injury, whether soiled with earth, grease, or manure, and whether considerably stained with blood, the latter

bearing upon the amount of hæmorrhage. The local examination should next follow. The condition of the skin, the size and appearance of the wound, the presence of protruding bone fragments, the character of the secretions, and the amount of local swelling are all points of importance by means of which the nature of the trauma, the character of the injury, and amount of wound contamination may be estimated.

Information Relating to the Skeletal Injury.— All information required as to the nature of the bony injury may usually be obtained by inspection alone or measurements to demonstrate shortening. Visible deformity is the rule, and if this is absent abnormal mobility is at once evident when the part is gently lifted. No attempt should be made to elicit crepitus. Articular involvement is indicated by the situation of the wound, the distention of the joint cavity, and the escape of synovial fluid, sometimes mixed with air, when pressure is made upon the joint.

Roentgen Examination.— Roentgenological examination should be made in all cases of wound by projectile in which the presence of a foreign body is suspected. If present, its position should be localized so that its extraction, if indicated, may be made easier. Roentgenological examination should not be made when it necessitates considerable delay in cases requiring immediate operation. It is also unnecessary in many cases when the nature of the injury is obvious and the type of trauma precludes the presence of a foreign body. However, in the majority of cases, it is of very real help and should be made whenever possible.

TREATMENT OF COMPOUND INJURIES

INDICATIONS GOVERNING TREATMENT

Different Methods of Treatment— The treatment will vary, depending upon the type of injury with which one is dealing. The attempt must be made to differentiate the uninfected from the potentially infected cases. The former may be treated by conservative methods to prevent the introduction of infectious material into the wound, while the latter require immediate operative treatment to prevent infection.

Differentiation of Infected and Uninfected Cases.— From what has been said concerning the causation and pathology of compound fractures, it is obvious that all cases should be regarded as potentially infected save those produced by internal violence in which the wound is tiny, with no possibility of the bone having protruded through the skin. Compound fractures, the result of bullet wounds, in which there is a minute wound of entrance and exit may be added to this group, but are rare except in time of war. Great accuracy is necessary in the differentiation of these two classes of cases, and disaster may follow an error. For this reason, whenever there is doubt, the case should be treated as if it belonged to the potentially infected group.

Influence of Complicating Conditions.— Considerations of a general nature will also play a part in determining the treatment. The presence of severe shock or hæmorrhage necessitates general rather than local treatment. The patient should be placed in bed, heaters applied, and morphine administered. Blood transfusion should be performed, or in the less severe cases, saline solution administered subcutaneously in large quantities and every effort made to improve the condition of the patient to the point where operation can be performed with safety. Other accompanying injuries must be appropriately treated and, depending upon their gravity, may take precedence over the compound injury and thus determine the treatment.

PROPHYLAXIS OF TETANUS

Routine Use—Tetanus antitoxin should be given routinely in every case of compound fracture. The protection obtained when it is given early is almost absolute, while, on the other hand, if treatment is begun only when symptoms appear, the mortality is extraordinarily high. To select the infected from the uninfected cases is almost impossible, and the only safe procedure is to use it in all cases.

Dosage and Repeated Administration.— The serum may be given subcutaneously and in dosage of 500 to 1500 units (U. S. A.). While the smaller dose is probably safe, added security is obtained from the larger quantity. Clinical and experimental investigation have shown that the immunity thus conferred has a very limited duration, that at the end of two weeks it is very slight, and at the end of three weeks it is practically gone. For this reason in the case of severe, badly contaminated wounds, the administration of the serum should be repeated at intervals of seven days until four doses have been given, unless primary healing has been obtained in the meantime. Because of the possibility of tetanus spores persisting in a healed wound for many months and of the danger that they may be stimulated to renewed activity by fresh trauma, whenever secondary operations are undertaken in old infected wounds even as late as a year from the time of injury, the injection of anti-tetanic serum should precede or accompany the operation.

Avoidance of Anaphylaxis.—To avoid anaphylactic phenomena, especially when there is a history of asthma, a small quantity of serum should be diluted with salt solution to a concentration of 1:10 and a few drops of the diluted serum injected intradermally. If, after a wait of 30 minutes there has been no local or general reaction, the remainder of the serum may be administered with safety.

PRIMARY OR FIRST-AID TREATMENT

Local Treatment of the Wound.— As soon as possible after injury the wound should be dressed and the fracture splinted for purposes of transportation. The clothing should be cut away from the part, the wound

covered with sterile gauze, and the dressing fixed with bandage. The skin surface in the region of the wound may be painted with iodine, but this should not be applied to the wound itself unless the orifice is tiny, because of the great pain which it produces.

Avoidance of Reduction.—No attempt should be made to reduce the fracture until the patient has reached the hospital. Particularly is this true in the type of case with bone protruding from the wound. It is obvious that infection in such cases results from the return of the bone to the soft parts. Usually this return occurs spontaneously immediately following injury, but, in many instances it is the result of the misguided efforts of a layman to apply what to him seems the proper first-aid treatment. Reduction of the dirty, contaminated bone is bound to be disastrous; rather should a sterile dressing be applied and the part splinted in its displaced position.

Splinting.— Proper immobilization should be applied immediately following injury, and it should be maintained until the place of permanent treatment is reached. The apparatus used is the same as in the case of simple fractures and has already been discussed in the section on Emergency Splinting. The necessity of immediate and complete fixation of a compound fracture for the purpose of transportation has been conclusively demonstrated in the war. It not only has an immediate effect in preventing shock and making transportation even over a considerable distance comparatively painless, but it also has a very important effect in reducing the chances of wound infection and preventing damage to uninjured structures by the grinding about of the bones.

I. TREATMENT OF COMPOUND FRACTURES WITH UNINFECTED WOUNDS

Selection of Cases.—As has been said before, practically the only cases which can be treated in this manner with safety are those in which the wound is the result of violence from within and in which the size of the wound orifice is too small (less than 1.25 cm. in diameter) to have permitted the protrusion of the bone through the opening and also those resulting from rifle bullets with tiny wounds of entrance and exit. The aim of treatment is to prevent the introduction of infection.

Care of the Wound.— The first care should be given to the surgical preparation of the skin. The region should be shaved over an area extending 12 to 18 inches above and below the wound. This should be done with the skin dry or moistened with benzine, and the shaving should be in a direction away from the wound, the latter being covered with gauze. The surgeon or an assistant should hold the limb while this is being done, exerting steady gentle traction and supporting the limb at the level of the fracture. After shaving, the part should be thoroughly cleansed with benzine and all dirt carefully removed. This should be followed

by the application of ether to dry the skin. Under no circumstances should the surface be washed with soap and water on account of the danger of washing into the wound infectious material from other parts. The wound should next be swabbed with full-strength tincture of iodine and the surrounding skin painted with it. A dry sterile gauze dressing of sufficient volume to absorb the secretions should then be applied.

Care of the Fracture.— After the wound has been dressed, the fracture should be reduced and splinted as if it were a simple fracture. If a plaster of Paris casing is applied, a large window should be immediately cut out over the wound, so that the dressing may be changed and the wound inspected whenever necessary. When a choice of fixative apparatus is possible, plaster of Paris should be avoided in most instances in favor of traction splints, which allow a wider exposure of the part. If extension is required, skeletal traction is usually to be preferred to adhesive traction, as the presence of the dressings interferes with the application of the adhesive strips and a sufficient area of skin to support the heavy pull is frequently unavailable.

The after-treatment of this type of case usually presents no problem different from that of a simple fracture. As a rule it is unnecessary to change the dressings before the end of a week or ten days. Careful watch should be kept of the temperature and pulse rate and if these rise unduly, the wound should be inspected. After wound healing has occurred, the treatment is the same as in the case of simple fracture.

II. WOUND TREATMENT IN CASES OF POTENTIALLY INFECTED COMPOUND FRACTURE

Operation should be undertaken as soon as the patient can be placed in surroundings favorable to its successful performance, and when his general condition is good enough to support the operative risk. The aim is to prevent the development of infection by removing from the wound all soiled and damaged tissues along with the major part of the infecting organisms.

Anæsthesia.—General anæsthesia is always indicated. Occasionally intraspinal anæsthesia may be of use. Local anæsthesia should be avoided in all cases because of the unfavorable effect of infiltrating the tissues with a large quantity of solution. This inevitably impairs their vitality and lowers their resistance to infection.

Surgical Preparation of the Region.— Preliminary to operation, the wound and surrounding skin should be given thorough surgical preparation to prevent the transplantation of bacteria from the cutaneous surface to the wound. The authors are accustomed to employ different technics, and as both have given satisfaction, each is described. The part should be cleansed with benzine and carefully shaved, the wound being covered with

sterile gauze. Following this, the surface is scrubbed with ether, and then painted with full-strength tincture of iodine. The alternative technic is as follows: Protect the wound with sterile gauze, and with the aid of sterile water and the tincture of green soap shave the surrounding skin. Then wash the whole limb with lysol diluted with sterile water and dry with sponges. Then apply Harrington's solution to the skin and to the wound itself, washing it off from the former with sterile water or saline solution. The application of strong antiseptics, such as full-strength tincture of iodine and Harrington's solution, to the wound is not harmful at this stage, as the tissues which are thus treated are to be removed in any case by débridement.

General Details of Technic.— For the operation itself, the most careful technic is required. The surgeon should employ instruments altogether in the handling of tissues and avoid putting the gloved finger in the wound. Frequent change of soiled instruments for fresh sterilized ones is necessary, and if the gloves become contaminated from the wound, they should be immediately changed or carefully washed in strong antiseptic solution. Great pains must be taken to avoid traumatization of healthy tissues by seizing them roughly with forceps. Retractors should be used gently. Sponge by pressure rather than by wiping, as the latter spreads infection into sterile parts. Careful hæmostasis must be obtained as blood clot favors the growth of bacteria. Avoid ligation *en masse*, as the tissue tied off is deprived of blood supply and furnishes excellent media for organisms. Deep sutures and ligatures should be made with fine catgut and the knots cut short. Suture and ligature material constitute foreign bodies and favor the development of infection.

The operation is best performed by the method of progressive excision of the walls of the wound. When possible this may be done by block removal to a considerable extent, but it is never possible to deal with the entire wound in this manner, and the danger is always of the excision of too much tissue. The surgeon should be especially warned against this fault, as it is one that has frequently brought the operation into disrepute.

Excision of Damaged and Infected Tissues.—The external wound opening should be excised with a surrounding strip of skin 7 mm. to 1.25 cm. wide. Complete access to the wound should then be obtained by an appropriate incision. The subcutaneous tissue, being less important, may be removed more widely. The walls of the wound where they are distinct may be excised *en bloc;* when this is not possible, the surfaces should be carefully inspected, and soiled and damaged tissue removed wherever found. When the blood supply is good, as indicated by free bleeding, it is sufficient to remove a layer 6 mm. thick. If, however, the normal oozing is absent, the tissue should be trimmed away until bleeding is encountered. Frayed and shredded fascia should be

excised. Blood clots should be removed and bloody infiltrations traced back along the fascial planes. Lacerated tendon sheaths should be opened and the tendons, depending upon their condition, either removed or thoroughly cleansed.

Treatment of Muscle Tissue.— Muscle tissue should be treated with great care. It should never be sectioned transversely beyond the part which needs to be removed, as it does not regenerate and there is also likely to be injury of the minute nerve fibres running within the muscle itself. However, it is the favorite site for the development of gas infection, and all damaged and soiled tissue must be thoroughly removed. Healthy muscle may be recognized by its normal color, the oozing of minute drops of blood on section, and its contractile response on stimulation with the forceps.

Treatment of the Bones.— The most meticulous treatment of the fractured bones is required. Complete exposure should be obtained, but the periosteum interfered with to as slight an extent as possible. Entirely free fragments of bone may be removed, but all those to which the periosteum is attached should be preserved. Soiled bits of bone should be removed with the rongeurs, and the other portions cleaned with gauze. The matter of reduction and fixation of the bones is discussed under the heading of treatment of the fracture (p. 56).

Treatment of Intra-articular Injuries.— When the injury involves an articular cavity, the opening in the capsule should be carefully exposed and its edges excised. To clean the joint cavity, free access is required, and if the original opening is not sufficiently large or well enough placed for this purpose, the required exposure should be obtained through one of the classical incisions. The synovial membrane should be respected, and irritation avoided by the use of sterile cotton pledgets wrung out in hot saline solution instead of by the ordinary gauze sponges. Blood clot should be wiped out, soiled and damaged cartilage removed, and the cavity washed with ether. The opening of the wound into the joint should then be closed either by the approximation of the capsular layers or, if these are not sufficient in amount, by fascial or muscle flaps. If an additional opening into the joint has been made by the surgeon, this should next be closed by suture of the various layers. If the external wound is dirty, it may be drained down to the closed capsular opening, but under no circumstances in a recent case should drains be inserted in the joint. Complete closure of the capsule is a principle of fundamental importance in the prevention of joint infection.

Removal of Foreign Bodies.— The treatment of metallic foreign bodies, if present, will depend considerably upon their size and location. When possible, they should be removed, but if small and not readily found, they may be left without great harm. Foreign bodies in a joint cavity

or in direct contact with the bone must always be removed. Previous localization by means of roentgen examination will greatly simplify the search.

Antiseptics and Lavage.—The value of antiseptics for wound disinfection at the time of operation is debatable. It is argued that they are not effective in destroying bacteria, that they irritate the tissues, and that there is danger of disseminating infection by the use of fluids. The authors believe that in general the antiseptic action is of little value, but that the mechanical cleansing effect of wound lavage may be of benefit. If the superficial parts are held widely open with retractors, the irrigating tube placed deeply in the wound, and the solution allowed to enter slowly, back pressure is avoided and the effect is to wash from within outward. One of the authors is accustomed to use neutral soap or tincture of iodine greatly diluted, or even plain saline solution. In no case should antiseptics be used in strength sufficient to irritate the tissues. If chemicals are used it should be understood that they are to supplement a thorough operation, but never as a substitute for it.

The Question of Wound Closure.— Having finished the débridement, the question of the closure of the wound should be decided. Shall it be left open or closed by primary suture? Shall drainage be employed or not? How these questions are to be answered will depend upon the nature of the accident, the time elapsed, the extent of the injury, and the surgeon's estimate of how far the operation has succeeded in achieving its object of preventing infection. In the hands of experienced surgeons, the method of primary suture either with or without the addition of the B. I. P. paste technic (see p. 45) may be employed in the majority of cases, particularly those with injuries involving the bones of the lower leg or the upper extremity. Wounds opening into the articulations should invariably be closed. Surgeons without great experience in the operation of débridement had better at first employ the method of delayed primary suture. Deep or excessively dirty wounds, or those which come under treatment only after a delay of twelve hours or more, or in which actual soiling of the bones is found at the time of operation, should be left open and tubes inserted for the immediate application of the Carrel-Dakin method of wound sterilization (see p. 42).

Drainage.— The matter of drainage is important. Drains constitute foreign bodies and as such are likely to act unfavorably on the tissues in their resistance to infection. On the other hand, their effect in preventing the accumulation of secretions in the wound is of value in promoting healing. When a wound is treated by primary suture, without the B. I. P. paste technic, it is usually best to drain with a small roll of soft rubber tissue, which may be removed at the end of 24 to 48 hours.

If the wound is left open, no drainage is required, particularly if the Carrel-Dakin method of treatment is employed.

Bacterial Examination.—In all cases the wound should be cultured at the time of operation, and a careful investigation should be made by a bacteriologist to identify the various organisms found. The finding of streptococcus hæmolyticus is a bad omen, and if primary suture has been performed reopening of the wound is likely to be necessary. The presence of gas bacilli should put the surgeon on guard, but is not of itself an indication for altering the plan of treatment. If the tissues are healthy, the chances for the development of gas infection are very slight.

After-care.—Following operation, the evolution of the wound may be followed by close watch of the temperature and pulse rate. Slight elevation of the temperature may be expected for the first few days, but it should then fall. Sudden elevation of the temperature or gradual rise of temperature and pulse are evidences of infection. More important than either as a guide is the symptom of pain. Slight soreness in the wound is the rule, but with good immobilization severe pain should not be felt. Pain and particularly a sense of constriction from the dressings are both bad signs and necessitate immediate inspection of the wound.

TREATMENT OF THE FRACTURE

Open Reduction Following Débridement.—Immediate reduction of the fracture followed by fixation in proper apparatus is indicated in all cases at the time of treating the wound. If the case belongs to the uninfected group, this will be accomplished by closed methods, as in the case of simple fracture. If, on the other hand, it belongs to the group requiring operative treatment, reduction should be performed by direct open manipulation of the bones, as the last step prior to the closure of the wound.

Open reduction may be accomplished by the method of angulating the fragments so that their ends project from the wound, then placing the two in apposition and straightening the limb, or by the method of traction and counter-traction, while the bones are grasped with instruments and pushed into place. If the ends of the bones are irregular, it is easy to make them lock in such a way that there will be little tendency to displacement. In other cases it is often possible to obtain the same interlocking effect by slightly trimming or notching the bones, but no complicated procedures should be undertaken for this purpose.

Internal Fixation not Advisable.—Of late years many surgeons have inclined to the application of metal plates or bands for the direct internal splinting of the bones in compound fractures. These were for temporary use only and were removed when union had occurred. Good results were obtained and the method was justified by the inability to secure alignment of the bones or satisfactory fixation with the apparatus then

in use. It is obvious, however, that such internal splints are foreign bodies and that their presence is detrimental to clean wound healing. Moreover, the various splints developed during the war for the treatment of compound fractures maintain reduction and alignment equally as well and are not open to the same objection. For this reason, the method has now been superseded, and only in rare and exceptional cases is the direct application of metal or other fixative materials to the bone advisable.

Methods of External Fixation.—The splints which are most generally useful for the treatment of compound fractures are those which provide integral traction. Traction maintains bony alignment without the necessity of local coaptation splints and thus allows free access to the wound. It is important from the start to splint every case in such a way that no matter what developments occur, change of apparatus will not be required. Alignment should be maintained and fixation provided continuously by one splint until union has occurred. Direct skeletal traction is usually to be preferred in compound fractures for the reason that skin traction necessitates the covering of a considerable part of the limb with bandage and thus interferes with free exposure of the part. With skeletal traction practically all of the injured part may be uncovered as required.

The general treatment, therefore, requires open reduction of the bones as an additional procedure to that of débridement, with the locking together of the ends of the fragments whenever this can be easily accomplished. The part should be carefully supported until the operation has been finished and the dressings applied, and then immediately immobilized by the use of appropriate traction apparatus designed to allow wide inspection of the part and easy change of the dressings.

AMPUTATION WITH REFERENCE TO COMPOUND FRACTURES

Under certain circumstances, primary amputation is advisable. Chief among these are: (1) Gross injury to bone and soft parts, so severe that recovery with useful function is unlikely even if healing and union can be secured. Included in this category are injury of the main vessels and nerves. (2) The impossibility of preventing virulent infection such as would endanger life. Two cases of fracture of both bones of the leg are brought to mind where an attempt was made to save the limb. A streptococcal septicæmia developed in each case and amputation did not avail to save life. Greater risks are justifiable in attempting to save the upper limb than the lower and in the case of a young subject. If amputation is decided upon, the primary mortality can be greatly reduced by treatment of the shock and loss of blood as a preliminary measure. Amputation may be called for later, because of spreading infection, osteomyelitis or gangrene; or on account of secondary hæmorrhage.

METHODS OF FIXATION TO BE USED IN INJURIES OF THE VARIOUS REGIONS

Below, in tabular form, are listed the apparatus and methods of splinting which should be employed in compound injuries of the various regions. The details of their application and use as well as a brief consideration of the special features of compound injuries as they relate to the individual bones will be found elsewhere in the different sections dealing with the appropriate region or fracture.

Part or Region Involved	Method of Fixation
Clavicle	Recumbency in bed or clavicular cross.
Scapula	Thomas arm splint with arm abducted or aeroplane splint.
Shoulder	Thomas arm splint with arm abducted or aeroplane splint.
Humerus (shaft)	Jones humerus traction splint.
Elbow	Modified Jones humerus splint or Blake suspension traction method.
Forearm	Direct overhead suspension or Jones humerus traction splint.
Wrist and Hand	Banjo traction splint.
Fingers	Wooden finger splints or small wire traction splint.
Spine	Anterior and posterior plaster shells.
Thorax	Circular chest swathe.
Face	No splint required except in case of jaws when special wiring of teeth or interdental splints are used.
Pelvis	Recumbency in bed on Bradford frame.
Hip	Special abduction traction splint (Crile).
Femur	Thomas leg splint with skeletal traction by means of calipers applied to femoral condyles.
Knee	Thomas leg splint, skin traction to leg, or Cabot posterior wire splint.
Leg	Thomas leg splint with skeletal traction by means of pin passing through or over the os calcis, or simple plaster fixation.
Ankle	Thomas splint with skeletal traction by means of pin passing through or over the os calcis.
Foot—Posterior Tarsus	Plaster cast with window cut over wound, or anterior moulded plaster splint.
—Anterior Tarsus	Plaster boot with banjo traction attachment.
Toes	Plantar splint of wood or moulded plaster.

CHAPTER IV

INJURIES OF THE SHOULDER GIRDLE

I. FRACTURES OF THE CLAVICLE

II. DISLOCATIONS OF THE CLAVICLE

1. Sterno-clavicular Dislocation

2. Acromio-clavicular Dislocation

III. FRACTURES OF THE SCAPULA

ANATOMICAL CONSIDERATIONS

Clavicle.—The CLAVICLE is a slender, doubly-curved bone which acts as a prop to keep the point of the shoulder out from the trunk. The usual site of fracture is the outer half of the middle third of the bone, where it is most slender structurally and receives least support from muscles and ligaments (Fig. 26). It is here also that the long anterior and short posterior curves of the bone meet.

The middle third of the clavicle is of importance beause of its relations to the subclavian vessels and brachial nerve trunks which pass directly beneath this section

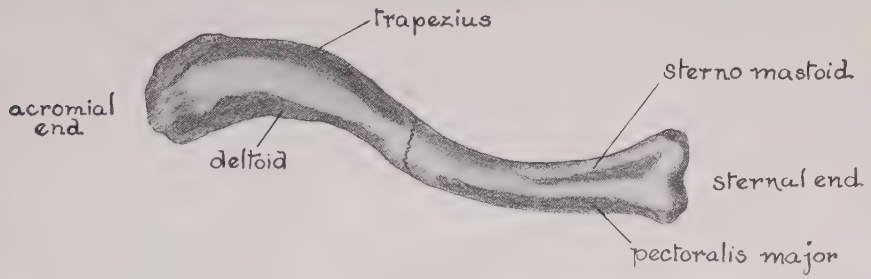


FIG. 26.—Right clavicle, upper surface, showing muscle insertions and common site of fracture.

of the bone, the subclavius muscle intervening. Injury to these structures is a rare complication of fracture chiefly because the common fracture site lies slightly external to their course. Later, involvement of the nerves in bony callus occurs rather more frequently.

The flattened outer extremity of the clavicle articulates with the acromion process of the scapula and is connected with the base of the coracoid process by the coraco-clavicular ligaments. When the site of fracture is through the attachments of these ligaments, but little displacement occurs. (Fig. 30.) When the fracture is external to that point, displacement takes place characteristically in the antero-posterior plane. The acromial end of the clavicle is turned forward at a sharp angle, usually by a fall on the back of the shoulder. (Figs. 27 and 28.)

Sterno-clavicular Joint.—The inner end of the clavicle articulates with the sternum to form the sterno-clavicular joint, and the slope of the articulation is downwards and outwards. (Fig. 29.) Its main source of strength is the costo-clavicular or rhomboid ligament, which binds the inner end of the clavicle to the first rib. It is this ligament which, by opposing the pull of the sterno-mastoid muscle, prevents upward tilting of the inner fragment in case of fracture.

FIGS. 27 and 28.—Fracture of clavicle, external to point of attachment of coraco-clavicular ligaments. Fig. 27.—Original deformity. Fig. 28.—Following application of clavicular cross. (Fracture Service M. G. H.)

Acromio-clavicular Joint.—The acromio-clavicular joint is formed by the junction of two flat bones with a small capsular ligament and is of itself inherently weak. (Fig. 30.) It derives its strength from the strong conoid and trapezoid ligaments which

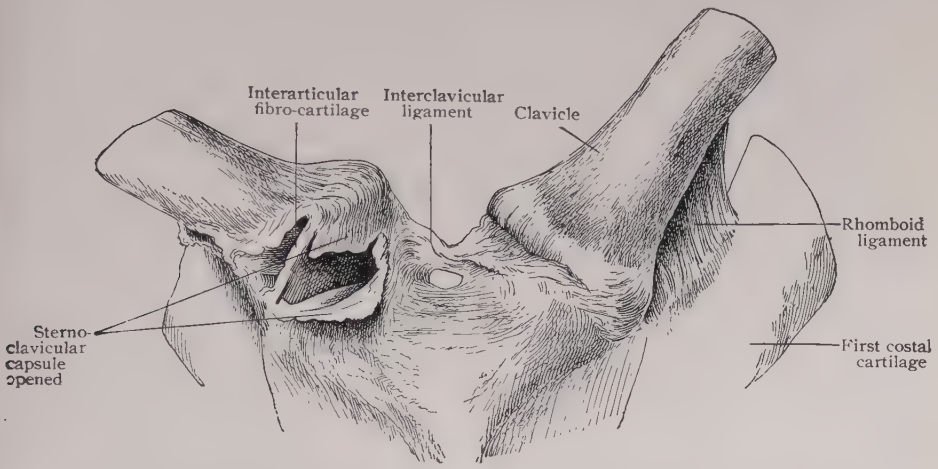


FIG. 29.—Sterno-clavicular articulation The right joint has been opened to show the intra-articular disc and the left clavicle is raised to show the rhomboid ligament. (Piersol's Human Anatomy.)

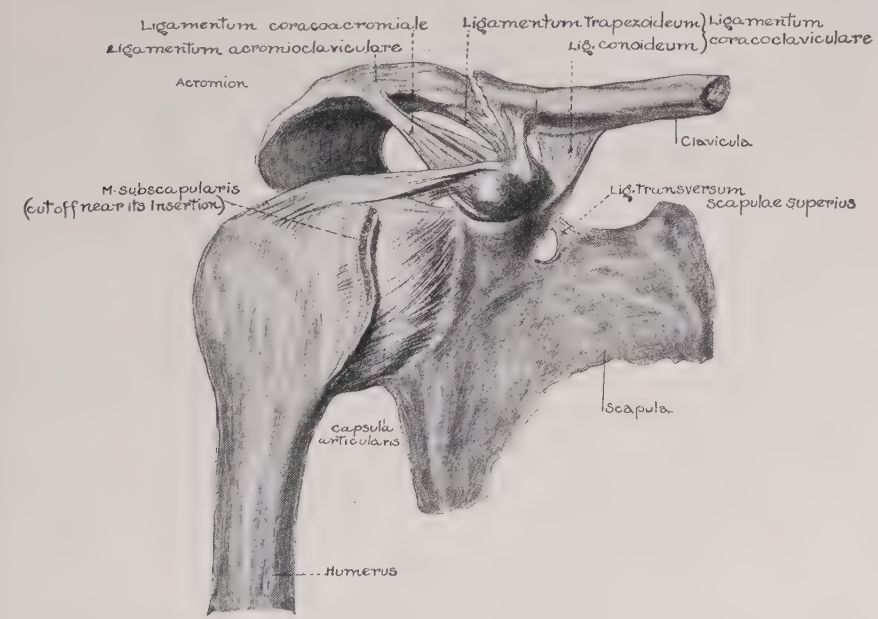


FIG. 30.—Acromio-clavicular articulation showing the arrangement of the supporting ligaments and the limiting effect of the latter upon displacement in case of fracture through the point of attachment of the coraco-clavicular ligament.

bind the coracoid process of the scapula to the overlying outer portion of the clavicle. Normally only slight motion occurs at this articulation but it adds considerably to the elasticity and resistance of the shoulder girdle to strain. The joint surface slopes

downward and inward, thus favoring upward dislocation of the clavicle. In cases of incomplete luxation, the injury is confined to the acromio-clavicular joint, but in complete dislocations the conoid and trapezoid ligaments are partly or wholly ruptured. (Fig. 30.)

Scapula.—The scapula is a flat triangularly shaped bone, divided on its posterior surface by the spinous process into the supra- and infraspinous fossæ. The acromion arises from the outer end of the spine. The superior, lateral angle of the scapula is thickened to support the glenoid from which it is separated by the neck, an important

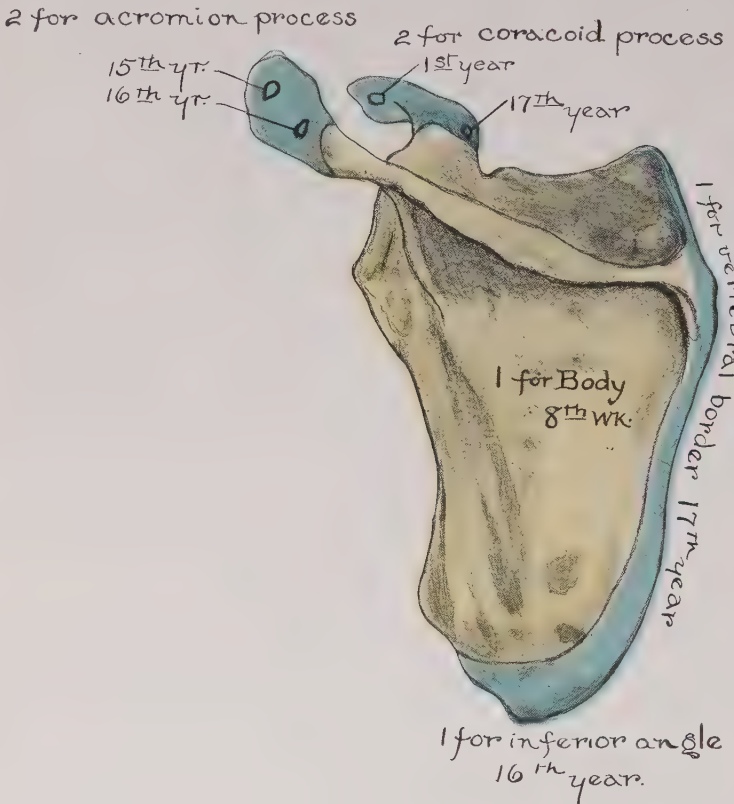


FIG. 31.—Left scapula, posterior surface, showing centres of ossification.

although infrequent site of fracture. The relative infrequency of fracture through the thin body of the scapula is explained by its thick protective covering of muscle and its great mobility. The common sites of fracture are indicated in Fig. 59. The ossification of the scapula is shown in Fig. 31.

Muscles.—The more important muscles in front are the pectoralis major and the pectoralis minor. The ventral surface of the scapula is covered by the subscapularis muscle which intervenes between the scapula and the ribs. To its vertebral border in front is attached the serratus magnus muscle (Fig. 520) which binds the scapula to the chest wall and in isolated fractures may help to displace the vertebral border towards the axilla. Posteriorly, is the trapezius muscle and beneath it the two rhomboid muscles and the levator anguli scapulæ, all concerned in raising and bracing back the shoulder.

Examination of the Shoulder Girdle.—Examination of the shoulder is best performed from behind, with the patient seated. The affected shoulder should be compared with the unaffected side. Inspection may reveal asymmetry in level of the shoulders,

swelling or evidence of muscle atrophy. With the thumbs resting upon the lower cervical spine, the fingers may be placed upon the clavicle, tracing its entire outline. (Fig. 32.) Motion of the shoulder girdle should be tested both actively and passively. The passive motions of the clavicle are best elicited by holding this bone with the fingers of one hand while the other hand grasps the prominence of the shoulder and moves it forward, upward or backward. Motion of the scapula may be tested by resting the open palm over its posterior surface, while the arm is abducted and adducted or the shoulder moved forward and backward.

FIG. 32.—Method of examining shoulder girdle.

I. FRACTURE OF THE CLAVICLE

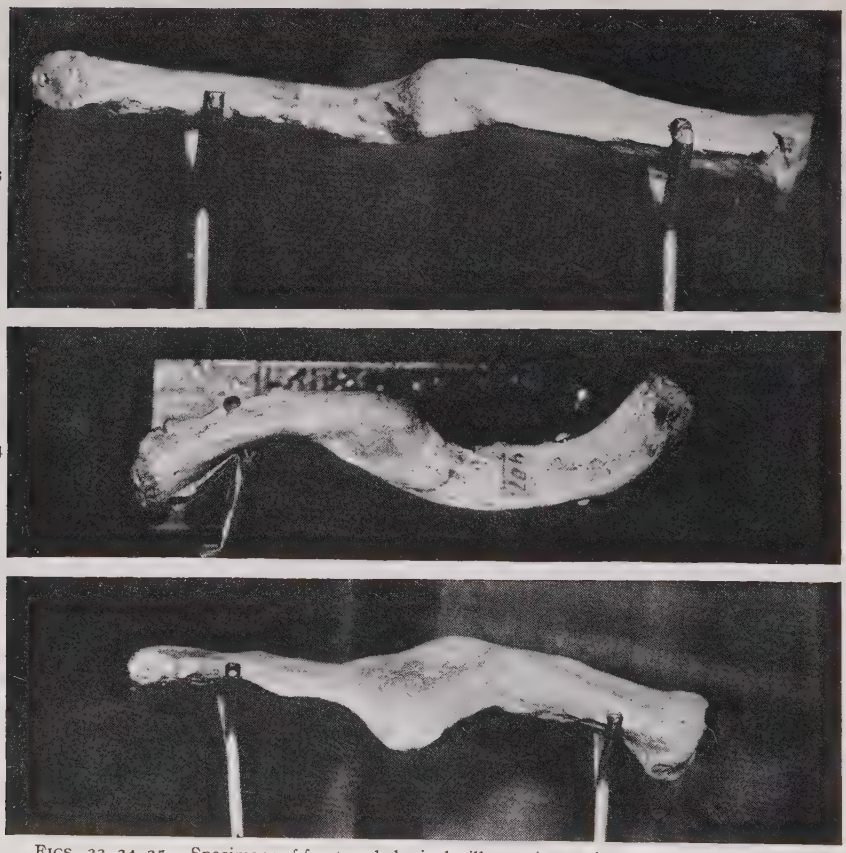
Causation.— Fracture of the clavicle is one of the commonest of all fractures and occurs with especial frequency in children, where it may be of the greenstick variety. In nearly all other cases it is complete, slightly oblique, seldom comminuted and almost never compound (see Figs. 33, 34, 35).

The fracture is usually due to indirect violence from a fall on the outstretched hand, the elbow, or shoulder. The shoulder is suddenly and violently elevated by the transmission of the force in an upward direction (Fig. 36). The clavicle being fixed at its inner end, the strain falls on the weakest part of the bone, with resulting fracture at the outer portion of the middle third.

Displacement.— The function of the clavicle is that of a prop to hold the shoulder back and out. When it is fractured, this support is lost and the shoulder falls forward, downward, and inward from the effect of gravity, the pectoral muscles assisting in the displacement. The outer fragment being fixed to the scapula by the coraco-clavicular and acromio-clavicular ligaments, moves with the shoulder and is displaced downward, forward, and inward (Fig. 37). The inner fragment moves but little from its original position, but may be displaced slightly upward by the sterno-mastoid muscle. There is over-riding of the fragments, the proximal one lying superiorly.

Fracture of the middle third may also result from direct violence or from violent muscular action. In such cases, the line of fracture is transverse, as a rule, and displacement not so extensive.

Diagnosis.— This usually presents little difficulty. There is first the history of a fall on the outstretched arm, the sensation of a bone snapping, immediate disability of the entire arm and pain in the shoulder. The appearance of the patient is characteristic, as he instinctively seeks to relieve the painful drag of the shoulder by supporting the flexed forearm



FIGS. 33, 34, 35.—Specimens of fractured claviculæ illustrating various types of deformity. (Warren Anatomical Museum.)

with the hand of the unaffected side (Fig. 39). The depressed position of the shoulder in comparison with the uninjured side is to be noted.

Locally, there is swelling and later ecchymosis over the seat of fracture. There is prominence of the distal end of the proximal fragment under the skin, readily discernable by palpation. There is localized tenderness on pressure. Abnormal mobility of the fragments and crepitus can be elicited by making passive movements of the shoulder.

In infants the diagnosis may be difficult, particularly when the fracture is of the greenstick variety (see Fig. 40). Usually the only his-

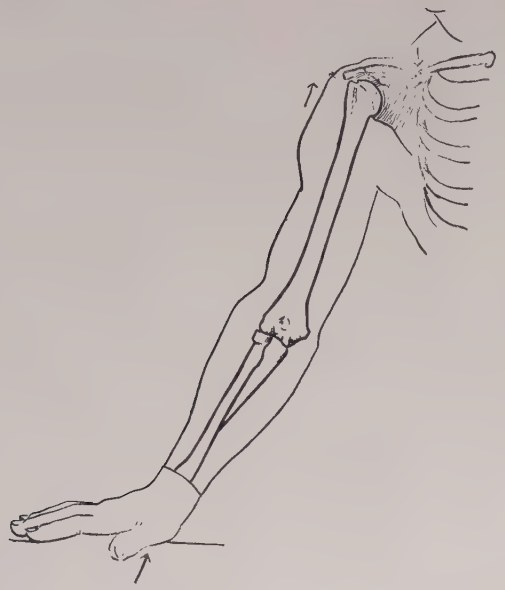


FIG. 36.—Fracture of clavicle by indirect violence, the force being received on the outstretched hand.

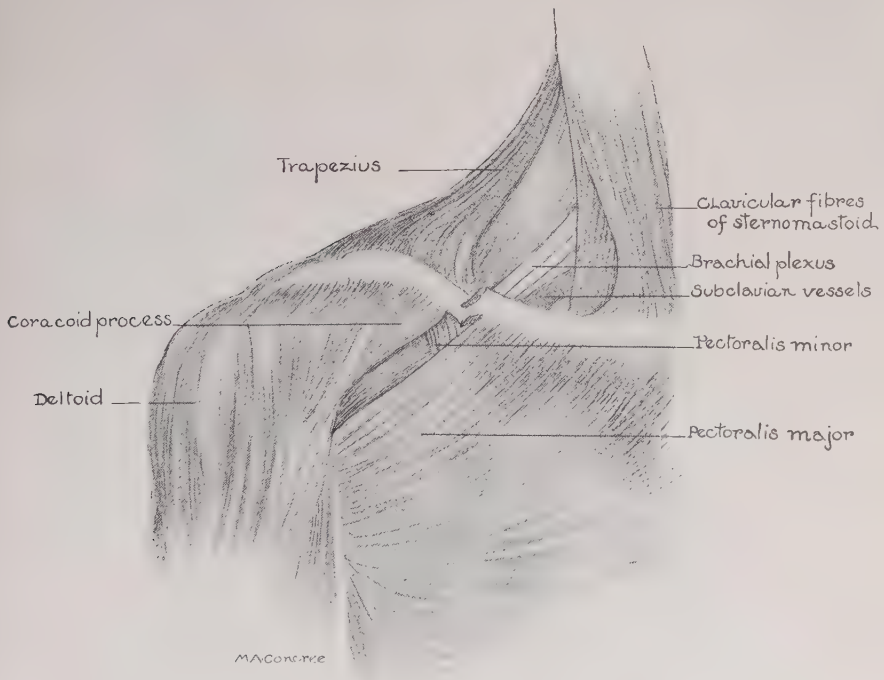


FIG. 37.—Fracture of the clavicle showing the classic displacement and relations of nerves and vessels.

FIG. 38.—Roentgenogram of fracture of clavicle showing classic displacement.

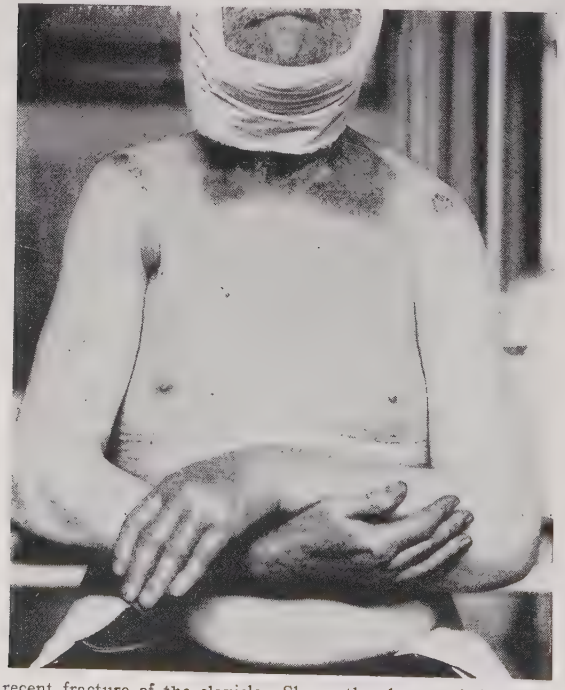


FIG. 39.—Case of recent fracture of the clavicle. Shows the characteristic manner of supporting the injured arm; also note the dropping of the shoulder and the extensive ecchymosis.

tory obtainable is that of a fall and disinclination to use the arm. Only a thorough and painstaking examination of the entire upper extremity will reveal the lesion in such cases.

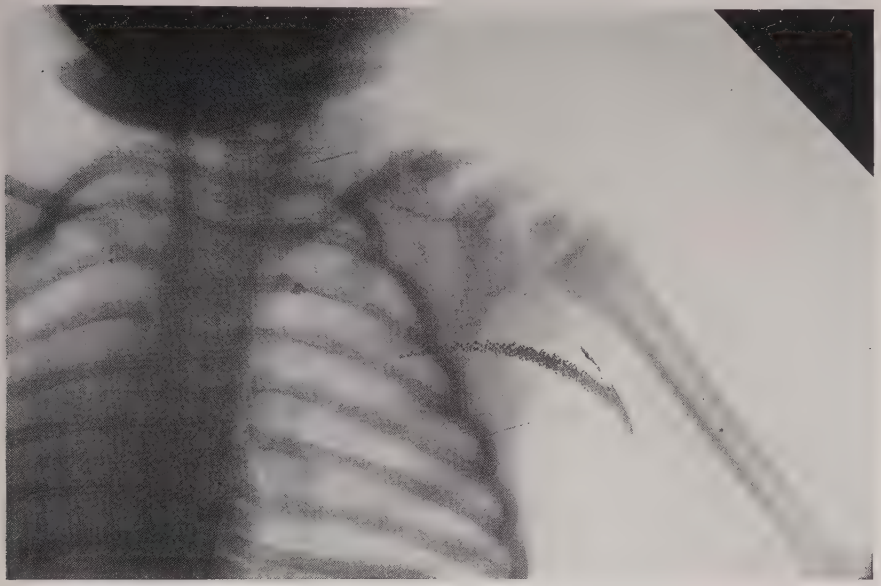


FIG. 40.—Fracture of the clavicle in an infant. This roentgenogram was made two weeks after injury. Note rapid callus formation.

FIG. 41.—Recumbent method of treatment for fracture of the clavicle. Patient lying on Bradford frame, elbow supported by sandbags. Wrist tied to neck by means of bandage.

Radiographic Examination.—A roentgenogram is seldom necessary for the diagnosis of uncomplicated fracture of the clavicle. It is, therefore, well to reserve it until after the displacement has been corrected, when it will also serve as a check on the position obtained.

TREATMENT

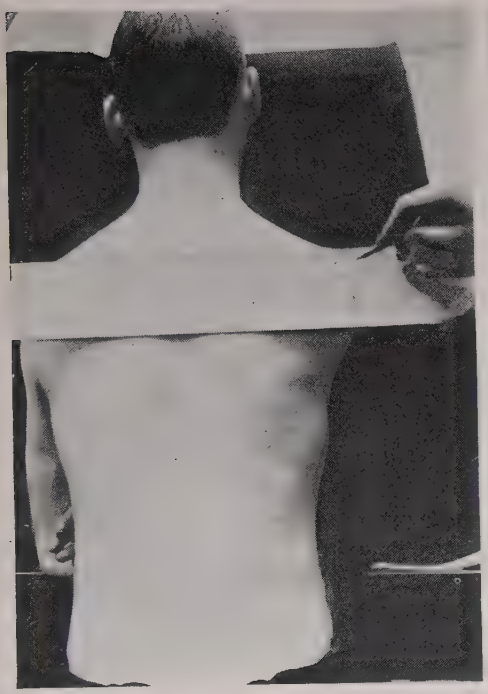
Indications.—The indications for treatment are to lift the shoulder upward, outward, and backward, which brings the outer fragment into alignment with the undisplaced inner fragment. When reduction has been secured, it may be maintained by strong backward fixation of the shoulders. Union is usually solid at the end of four weeks.

Recumbent Method.—There is no doubt that the best replacement of the fragments is obtained by the method of recumbency (Fig. 41). With

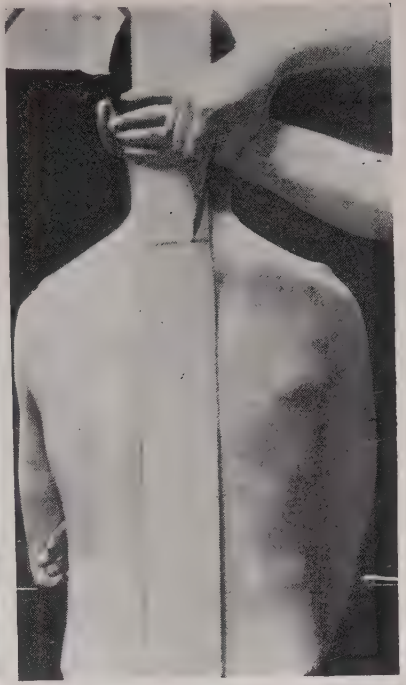
FIG. 42.—Fracture of clavicle, following reduction. Shows alignment obtained by the recumbent method of treatment. (Fracture Service, M. G. H.)

the patient flat upon the back and a small sand bag between the shoulders, gravity is thereby made to act as a corrective, instead of a deforming, force. The weight of the shoulder pulls the outer fragment back, out, and up, and secures and maintains good alignment (see Fig. 42). On the other hand, the results obtained by the ambulatory method of treatment, although less perfect anatomically, are functionally excellent. Practically the difference in results is one of cosmetic importance only. The recumbent method gives a smaller amount of callus and will, therefore, be preferred in the case of women who consider the appearance of their shoulders. In others this advantage will seem of doubtful value when obtained only at the cost of several weeks' confinement in bed.

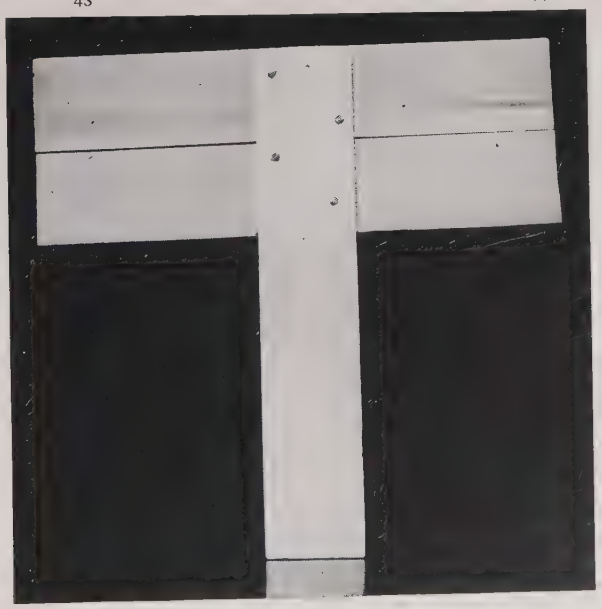
Recumbency, when used, should be maintained for three weeks. The patient may be better cared for if placed on a Bradford frame. The elbow



43



44



45

FIGS. 43, 44 and 45.—Clavicular cross. Method of measuring and making splint. (43) Cross arm is width of shoulders. (44) Vertical portion extends from the cervico-dorsal region to the hollow over the upper part of the sacrum. (45) Splint assembled.

is raised, the wrist fixed to the neck by a bandage, and the arm steadied by sand bags. During the fourth week the patient may be out of bed with a sling. Light massage may be begun at once, and passive and supported voluntary motion at the end of two weeks.

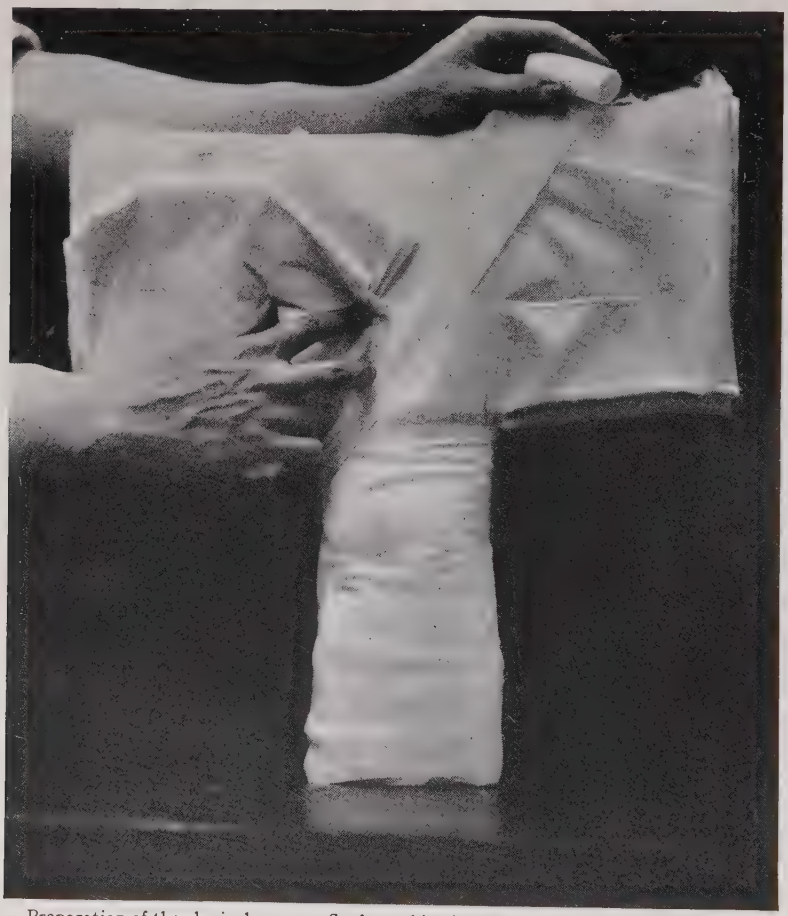
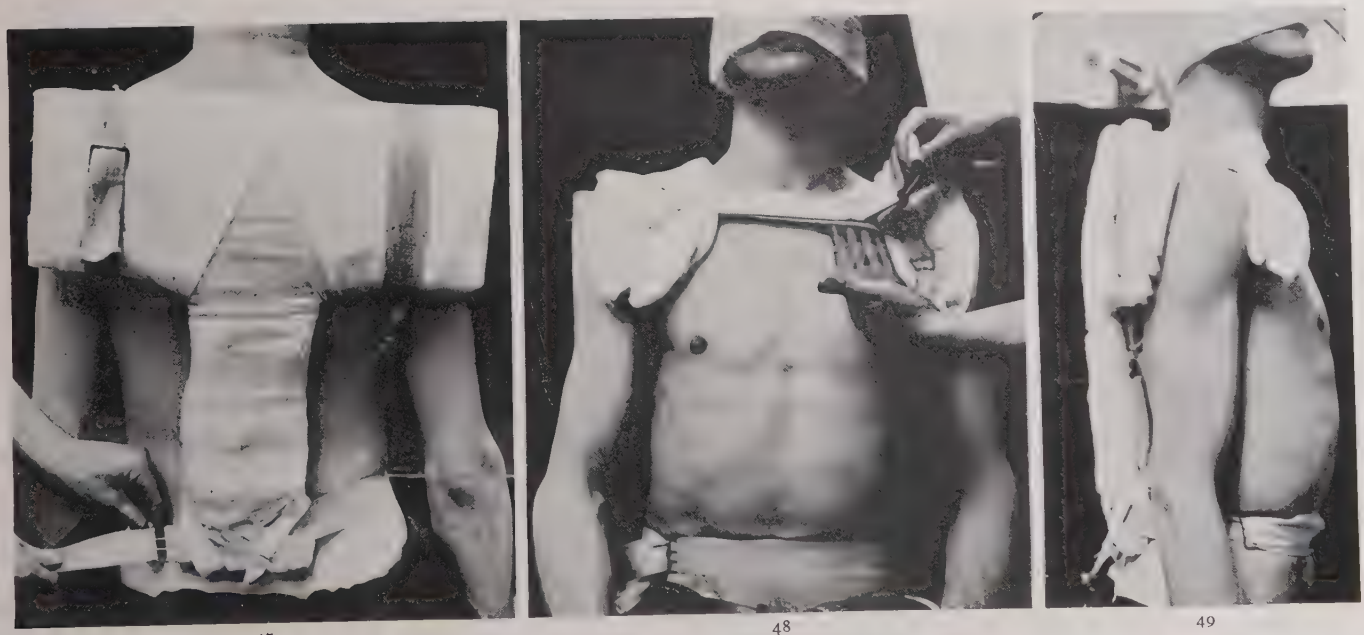


FIG. 46.—Preparation of the clavicular cross. Surface which is to be applied against the skin is abundantly padded with cotton wadding which is retained with a bandage.

Ambulatory Treatment.—For ambulatory treatment we have definitely discarded the Sayre apparatus, Velpeau bandage, etc., in favor of the clavicular cross (Figs. 43, 44, 45). This splint meets the indications better than any other apparatus we know and has the advantage of allowing freedom of the arm.

Clavicular Cross.—The clavicular cross is made from ordinary splint wood and is, therefore, easily obtained. The surface in contact with the skin must be abundantly padded (see Fig. 46). The crosspiece for



47 48 49

FIGS. 47, 48 and 49.—Application of the clavicular cross. (47) Cross is applied with patient lying. Shoulders are strapped back to the ends of the horizontal piece, and the lower end of the vertical portion is strapped to the pelvis. (48) Front view. Shoulder straps are retained in position by connecting them with a buckled strap. (49) Splint applied, showing how shoulders are braced backward.

the shoulders should be made with a double width of splint board to prevent an upward and painful pull by the straps passing under the axilla. Thick pads of felt or sheet wadding should protect the shoulders from the straps anteriorly. A connecting cross strap is required in front to prevent the shoulder straps from slipping downward. The splint is applied and the shoulders tightly fixed to the crosspiece (see Figs. 47–49).

FIG. 50.—Convalescent treatment of fractured clavicle. Figure-of-eight bandage about shoulders and sling. The ends of the latter may be attached to tapes as shown which are crossed over the back, and then carried around in front and tied at the back. This is a substitute for tying the ends of the sling behind the neck and does away with the knot which often causes unpleasant pressure.

The affected shoulder is then lifted up and back while the lower end of the vertical portion of the splint is pushed in against the sacrum and fastened by an adhesive swathe, four inches wide, encircling the pelvis. No support to the arm is necessary, and motion may be allowed from the beginning. The apparatus may be discontinued at the end of four weeks.

Treatment in Infants.— In the case of infants with fracture of the clavicle, a lighter and less cumbersome dressing should be used. We are in the habit of using a soft flannel bandage applied as a figure of eight over both shoulders with the turns crossing behind. A large pad of felt or sheet wadding wrapped in bandage should be inserted between the scapulæ underneath the bandage to increase the backward pull on the shoulders.

Emergency treatment may well be carried out by supporting the elbow by a sling, at the same time bracing back the shoulders by means of two handkerchiefs placed well out on the shoulders and tied between the scapulæ.

Operative treatment may sometimes be required when other means of retention have failed, in the event of non-union or for the relief of pressure on the subclavian artery or brachial nerve trunks. Non-union is rare.

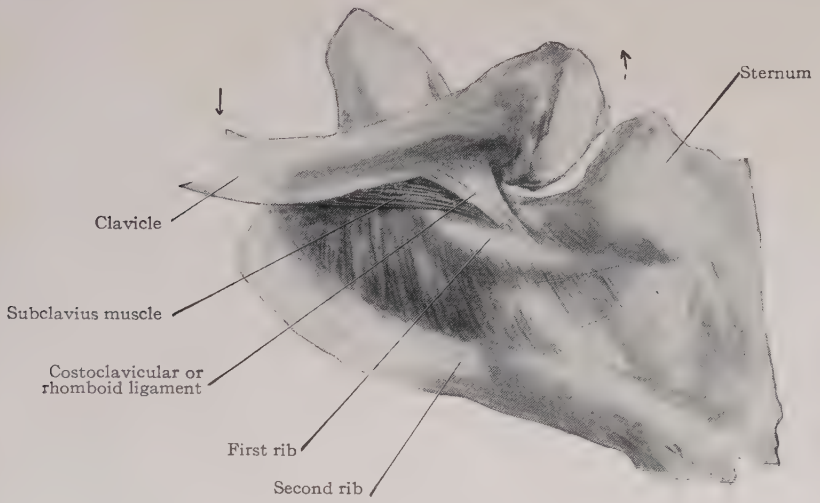


FIG. 51.—Dislocation of the sternal end of the clavicle upward and forward, showing how the first rib acts as a fulcrum and the clavicle as a lever. (Davis: Applied Anatomy.)

II. DISLOCATIONS OF THE CLAVICLE

I. STERNO-CLAVICULAR DISLOCATION

Mechanism.— The sternal end of the clavicle may be dislocated forwards, backwards, or upwards, the first-named being the most common variety. The mechanism of the dislocation is seen in cases of violent depression of the shoulder such as a fall upon it, when the first rib acts as a fulcrum to lever the sternal end of the clavicle out of the joint, with rupture of the sterno-clavicular ligaments (Fig 51). The costo-clavicular ligament usually remains intact; the interarticular fibrocartilage usually follows the clavicle.

In cases of backward dislocation, the sternal end of the clavicle takes up a position behind the manubrium and the muscles attached to it, and in this situation may exert injurious pressure on the trachea and œsophagus and other structures in the root of the neck.

Treatment.— The displacement is quite evident clinically in all these types of dislocation, and reduction is usually not difficult by local manipulation combined with the bracing backwards of the shoulder. It is difficult

to retain the bone in position, however, and the surest way is to treat the patient by recumbency with the shoulders braced back as in fracture of the clavicle. The alternative is to support the arm by a sling and bandage the arm to the side for a week, using local pressure on the sternal end of the clavicle by a felt pad and strips of adhesive. After that time the patient is allowed to begin supported motion. Persistence

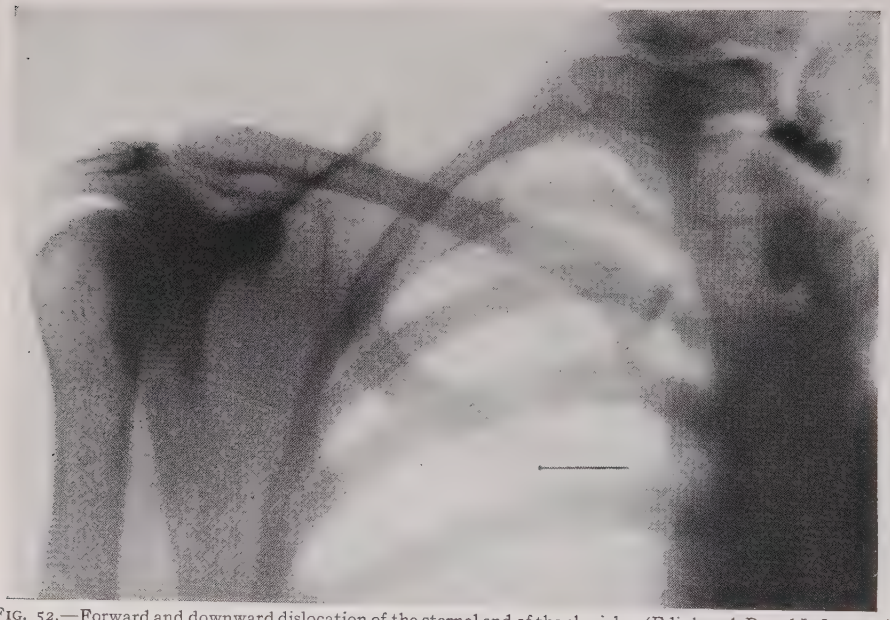


FIG. 52.—Forward and downward dislocation of the sternal end of the clavicle. (Edinburgh Royal Infirmary.)

of slight deformity and relaxation of the joint are not necessarily incompatible with good function.

II. ACROMIO-CLAVICULAR DISLOCATION

Varieties.—Dislocation of the acromial end of the clavicle may be upward or downward in relation to the acromion process of the scapula; the former is the more common, and the downward and mesial slope of the joint-surfaces would explain its greater frequency.

Mechanism.—The injury of upward dislocation results usually from a blow applied to the back of the acromion process or a fall on the tip of the shoulder. The acromion process is driven downward, inward, and forward, and the clavicle, with the coracoid process as a fulcrum, is thereby torn from it (see Fig. 53). The luxation may be complete or incomplete and in the former case the coraco-clavicular ligaments are ruptured. Downward dislocation from a blow on the clavicle or a fall

on the elbow is much rarer. The outer end of the clavicle is overriden by the acromion process, which stands out prominently.

Diagnosis.— Subluxation of the joint is a common football injury, and as replacement may occur spontaneously in such cases, the diagnosis rests chiefly on the nature of the injury, tenderness localized sharply over the joint, and pain at the same location on motion of the shoulder.

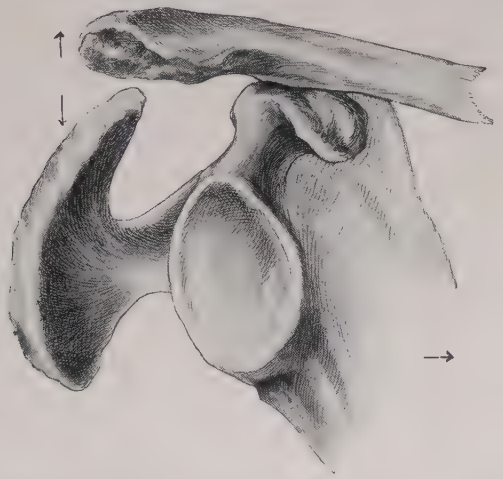


FIG. 53.—Dislocation of the acromio-clavicular articulation. Luxation of the outer end of the clavicle upward showing the coracoid process acting as a fulcrum. As the outer end of the clavicle rises, the lower angle of the scapula is carried toward the median line and the acromion process is depressed and torn loose from the clavicle above. (Davis: Applied Anatomy.)

In true dislocation, well-marked deformity is evident (see Figs. 54, 55). The tip of the shoulder is displaced downward, forward, and inward, and the displaced bones are distinctly felt in their new positions. Shoulder movements, especially abduction, are restricted and painful.

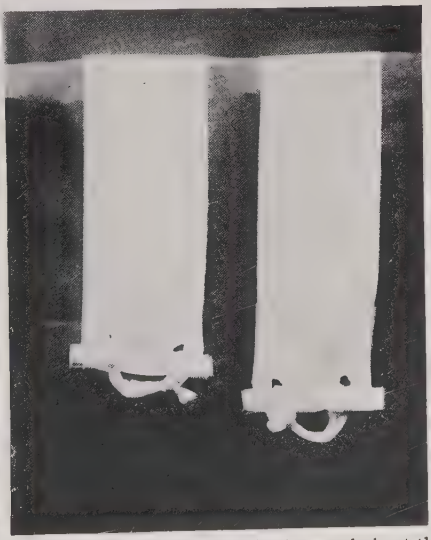
Treatment.—It is usually easy to replace the bones by lifting the arm and by local manipulation, but they are not easily held reduced if the coraco-clavicular ligament is ruptured. Permanent relaxation of the joint with considerable displacement frequently occurs as a result of failure of the torn ligaments to unite.

The brachio-clavicular sling, or modification of it, is the best means of retention (see Figs. 56, 57, 58), supplemented if necessary by a circular body bandage limiting the motion of the arm. In a limited number of cases with considerable separation, open operation may be required with a view to obtaining ankylosis, but it should be borne in mind that many cases with considerable relaxation suffer surprisingly little disability after continued supportive treatment.

54 55

FIGS. 54 and 55.—Recent case of acromio-clavicular dislocation. (54) Front view. Note the prominence of the acromial end of the right clavicle and the dropping of the shoulder. (55) Posterior view showing the same deformity.

FIG. 56.—Brachio-clavicular sling used in case of acromio-clavicular dislocation.



FIGS. 57 and 58.—Modification of the brachio-clavicular sling. (57) Adhesive sling is passed about the elbow and secured to a second strip coming across the top of the shoulder. The two strips are held together by a piece of strong elastic tubing which thus provides the necessary tension. The wrist is supported by a separate bandage sling. (58) Method of arranging the adhesive strips used in this dressing.

III. FRACTURES OF THE SCAPULA

Varieties.— Fracture of the scapula is a rare injury and may take the form of a fracture of the body, surgical neck, acromion or coracoid process (Fig. 59). Although thin, the scapula is protected by its mobility and covering of overlying soft parts; also it lies cushioned by muscle upon the yielding thorax, and before fracture can occur, the force—usually

FIG. 59.—Left scapula, anterior view, showing the different sites of fracture. (a) Fracture of the acromion process. (b) Fracture of the neck. (c) Fracture of the body.

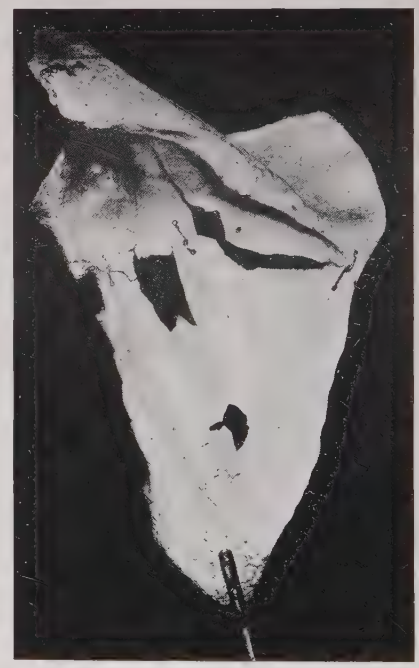


FIG. 60.—Comminuted fracture of the body of the scapula. (Warren Anatomical Museum.)

a direct form of violence—has to undo the natural arches of the bone, longitudinal and transverse. The most common fracture is through the body, and the lines of fracture run obliquely or transversely through the infraspinous fossa. It is usually comminuted (Fig. 60).

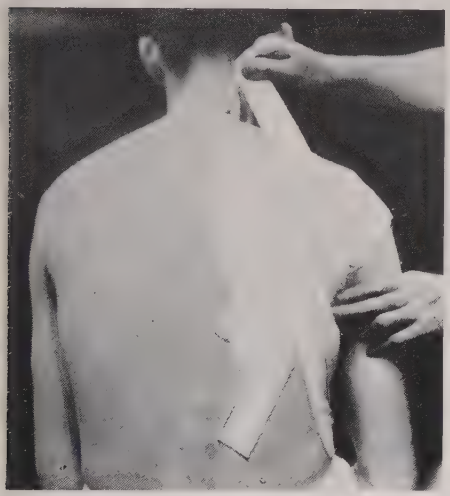
Diagnosis.— Local tenderness and pain are features. The pain is aggravated by attempted use of the limb, especially abduction, the action of the deltoid requiring the operation of the scapular muscle proper to fix the scapula as the first part of the movement of abduction.

Crepitus may be elicited, the displacement generally being one of slight over-riding from forward displacement of the vertebral fragment by the serratus magnus. Local swelling is usually well-marked from injury of the overlying soft parts, the density of the deep fascia overlying

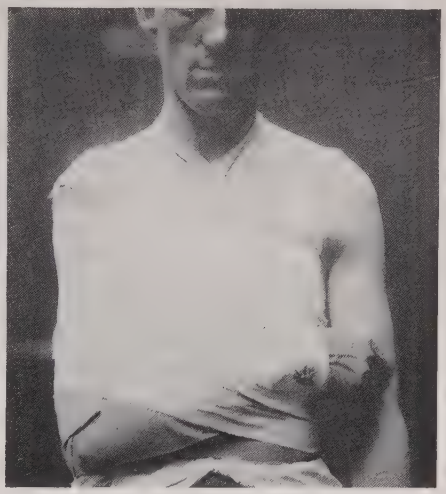
the supraspinatus and infraspinatus muscles preventing ecchymosis. Fracture of the scapula is rarely compound.

Roentgenologic Examination.—A roentgenogram will usually demonstrate the precise nature of the fracture. The exposure is best made obliquely through the axilla, with the arm abducted and pulled forward. In this position the ribs interfere to the least extent with the view of the scapula, and fairly accurate detail may be obtained.

Treatment.— As displacement is unimportant, immobilization until union has begun is all that is required. This may be obtained by a brachial sling



61



62

FIGS. 61 and 62.—Fracture of body of the scapula. Method of fixation. (61) Application of crossed adhesive strapping to fix scapula. (62) Dressing completed by addition of a sling and circular bandage.

and circular body bandage. Adhesive strips may be used during the first week as shown in figure 61, but should then be removed to permit massage. The completed dressing is shown in figure 62. Early use of supported movements of the shoulder is important and should begin the first week.

FRACTURE OF THE NECK OF THE SCAPULA

The fracture runs from the suprascapular notch to the axillary border of the scapula and detaches the glenoid cavity and coracoid process from the rest of the bone (Fig. 63).

Displacement.— The tendency in displacement is for the coracoid process and glenoid to be carried downward by the weight of the limb, but in the majority of cases this is counteracted in great measure by resistance of the coraco-acromial and the coraco-clavicular ligaments, which are intact. It is rare to see the classical type of complete fracture of the surgical

neck with a deformity which can at once be reduced by supporting the arm and which recurs as soon as the support is removed. The lesion usually partakes of the incomplete form with little or no displacement and recovers with very little final disability (Fig. 64).

Diagnosis.— In the complete cases, with stretching or tearing of the coraco-acromial and coraco-clavicular ligaments, the condition may closely simulate that of dislocation of the shoulder. In both there is increase

FIG. 63.—Fracture of the neck of the scapula, showing downward displacement of the glenoid.

in the length of the arm and flattening of the shoulder from overstretching of the deltoid; in both, too, it is possible to demonstrate a distinct depression just beneath the acromion process of the scapula. It differs from dislocation in that crepitus may be elicited when the deformity is reduced and also in the ease with which the deformity recurs following correction.

Treatment.— In the incomplete cases without displacement, massage and active motion should be employed from the beginning, a sling to support the elbow and circular body bandage being all that is necessary in the way of fixation. In the case of a complete fracture with displacement the authors recommend preliminary manipulative reduction by traction on the arm, followed by the application of continuous extension in conjunction with a Thomas arm splint, the arm being in the position of abduction and external rotation. (See pp. 108, 109, 110, and Figs. 108, 109.) This should be employed for three to four weeks, followed by the use of a sling for a like period, with daily massage and movement of the shoulder.

FIG. 64.—Roentgenogram of case of fracture of neck of the scapula, showing downward displacement of the glenoid and head of the humerus. (Fracture Service, M. G. H.)

CHAPTER V

INJURIES IN THE REGION OF THE SHOULDER

I. DISLOCATION OF THE SHOULDER

II. INJURIES OF THE UPPER END OF HUMERUS

1. Fracture of the Surgical Neck
2. Separation of Upper Humeral Epiphysis
3. Fracture of Anatomical Neck
4. Fracture of the Greater Tuberosity

ANATOMICAL CONSIDERATIONS

General Topography.—The shoulder-joint and tendons in immediate relation to it (supraspinatus, infraspinatus, and teres minor behind and the subscapularis in front) are concealed beneath the overhanging coraco-acromial arch of the shoulder girdle and

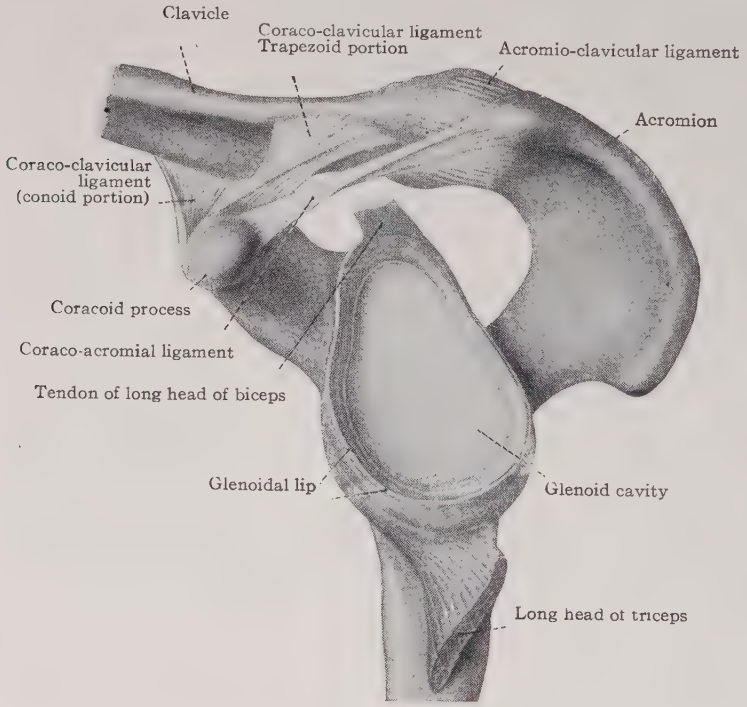


FIG. 65.—View of glenoid and of coraco-acromial arch. (Sabotta: Human Anatomy.)

by the fibres of the deltoid muscle, which together form the smooth, rounded contour of the shoulder.

The greater tuberosity, situated below and anterior to the tip of the acromion, may be palpated through the fibres of the deltoid muscle and felt to rotate on movement of the humerus. The lesser tuberosity points directly forward and lies one inch laterally to the coracoid process and beneath the anterior fibres of the deltoid. It forms the

inner boundary of the intertubercular groove, to whose outer lip, floor, and inner lip are inserted respectively the pectoralis major, latissimus dorsi, and teres major muscles. The long tendon of the biceps, lying in the intertubercular groove, may be located by a line drawn vertically upward through the middle of the biceps muscle. With the arm adducted to the side, and the examining hand in the axilla, one can readily palpate the mesial portion of the head and the surgical neck of the humerus (see Fig. 66).

Upper Humeral Epiphysis.—The upper epiphysis of the humerus is formed at about the seventh year by the fusion of the separate centres of ossification for the head, the greater and the lesser tuberosities. The epiphysis thus formed unites with the shaft between the twentieth and the twenty-fifth years. Medially the epiphyseal line coincides with the edge of the articular surface of the humerus, but laterally passes distal to the

FIG. 66.—Method of palpating the head of the humerus bi-manually.

tuberosities. Special notice must be taken of the conical shape of the epiphysis, an arrangement which resists separation and displacement.

Shoulder-joint.—The shoulder-joint is structurally weak as regards its osseous and ligamentous components, evidenced by the shallowness of the glenoid cavity, the relatively large size of the head of the humerus, and the laxity of the capsule, which is thin and loose and capable of accommodating a much larger object than the head of the bone. What the joint loses in stability by its architectural arrangement, it gains in mobility and range of action. Its strength lies in the protection afforded by the peculiar disposition of the strong supporting muscles and the accommodative control of the long tendon of the biceps muscle (Fig. 68).

Arrangement of the Muscles.—In analyzing the muscles of the shoulder from the standpoint of function, it will be seen that they are arranged in the form of a double cone, a short inner one, and a larger outside one which embraces the first. The inner cone is composed of the four muscles attached to the tuberosities, the supraspinatus, infraspinatus, teres minor and subscapularis (Fig. 68), while the outer cone is formed by the pectoralis major, latissimus dorsi, and teres major, which insert distally to the tuberosities (Fig. 69). The surgical neck, free of muscle attachments, lies between the insertions of the two cones. This conical disposition of the muscles is an important factor for strength, as it not only reinforces the capsule, but also provides a firm steady pull on the humerus, tending to hold it in the glenoid. The deltoid muscle overlies and protects the joint, but cannot be regarded entirely as a source of strength, as it produces the movement of abduction, which brings the head of the bone to bear upon

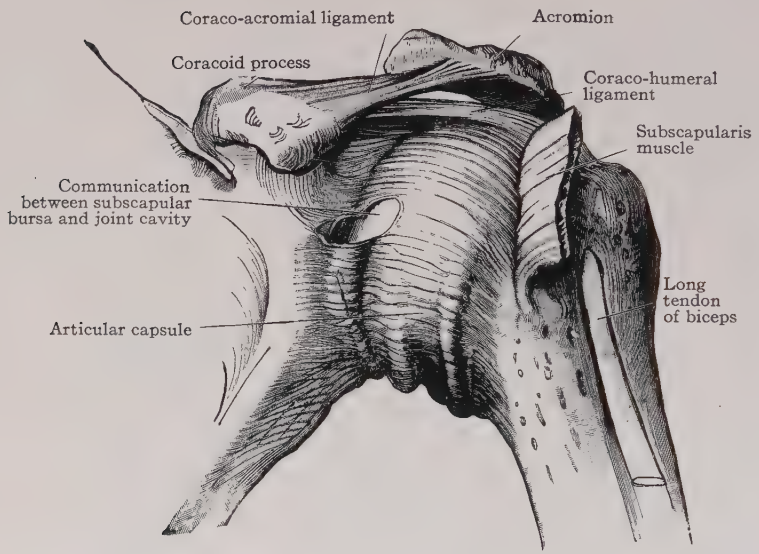


FIG. 67.—Shoulder-joint from in front, showing capsule. (Cunningham: Text-book of Anatomy.)

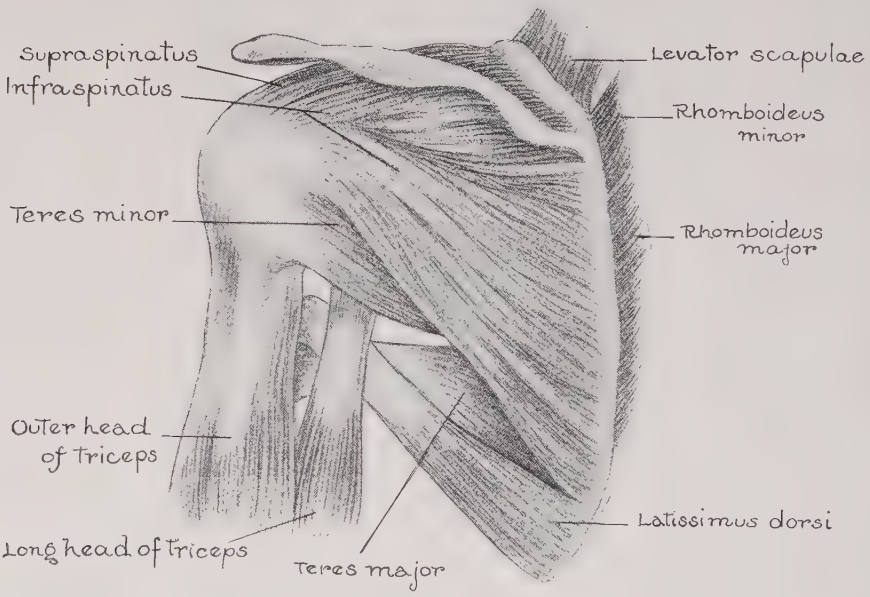


FIG. 68.—Shoulder-joint. Arrangement of inner layer of muscles. Note supraspinatus, infraspinatus, and teres minor attached to greater tuberosity.

the capsule inferiorly, the only part of the joint unprotected by muscles. Here the head of the bone is related to the quadrilateral space and axillary nerve.

Synovial Relations.—On the humeral side, the capsule of the joint is attached to the anatomical neck laterally and to the surgical neck medially. The lateral portion of the epiphysis is extracapsular; medially it is intracapsular (Fig. 70), so that the joint

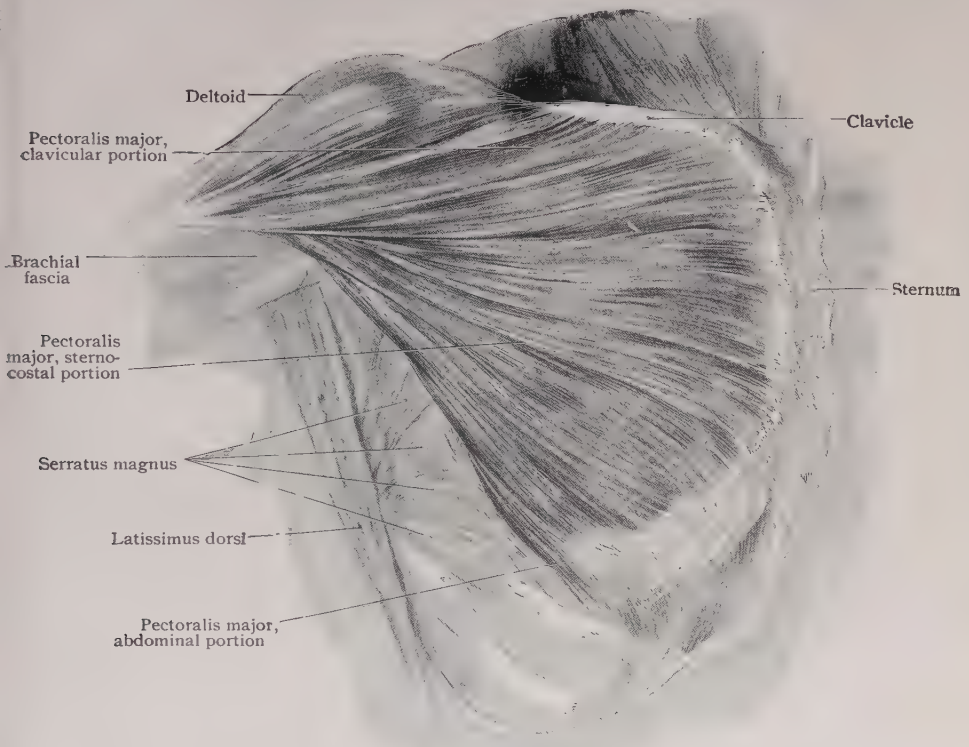


FIG. 69.—Anterior view of the region of the shoulder to show the superficial layer of muscles. (Piersol: Human Anatomy.)

is necessarily involved in separation of the epiphysis, and frequently so in fracture of the surgical neck.

The long tendon of the biceps, intra-articular but extrasynovial, is retained in the intertubercular groove by the transverse ligament, which must be torn before the tendon can be displaced.

Consideration of the attachment and course of the long head of the biceps makes evident its importance in retaining the head of the humerus in position, an action it can perform the more effectively by variations in its tension.

Subdeltoid Bursa.—The position and function of the subdeltoid bursa are important in connection with stiffness of the shoulder-joint following dislocations and fractures in the vicinity. It is a large bursal sac which intervenes between the acromion and deltoid above and the tendon of the supraspinatus and joint capsule below. Its function is to facilitate motion between these structures. When partially or completely obliterated by adhesions, the motions of the shoulder, especially abduction and external rotation, are markedly restricted.

Movements of the Shoulder-joint.—The shoulder is a ball-and-socket joint and permits motion in every direction. The pectoralis major and anterior fibres of the deltoid are concerned in flexion or forward motion of the shoulder, which is possible through a range of nearly 180 degrees. Extension, or backward motion, has a range of forty-five degrees and is carried out by the latissimus dorsi and teres major muscles. The motion of abduction is begun by the supraspinatus and carried to ninety degrees by

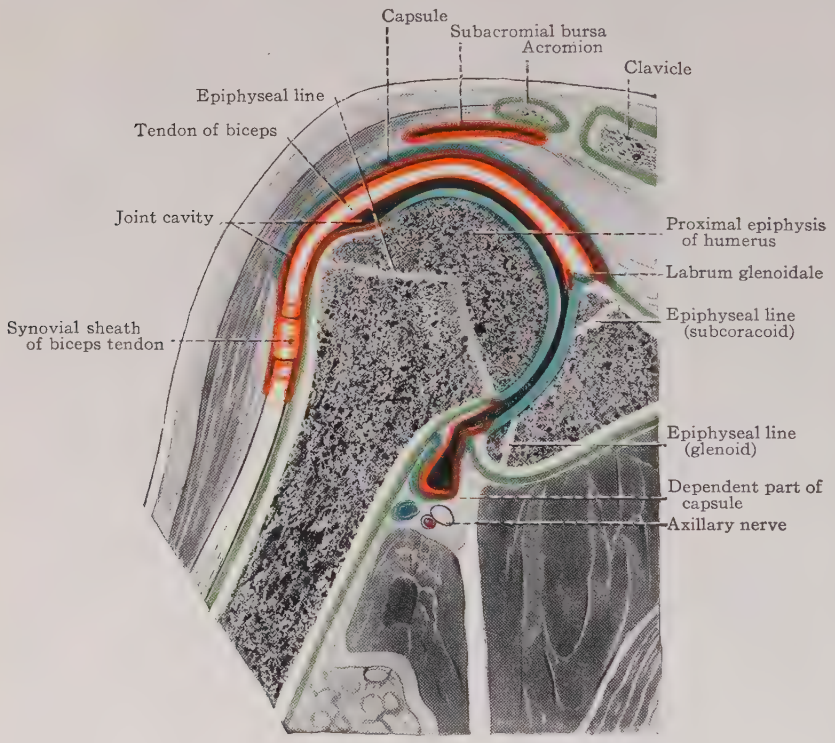


FIG. 70.—Frontal section through the right shoulder-joint, showing relations of the capsule, the epiphyseal line, and the tendon of the biceps. (Beesley and Johnston: Manual of Surgical Anatomy.)

the deltoid. Abduction beyond this point is not possible in the shoulder-joint itself, but is effected by the tilting of the scapula by the trapezius and serratus magnus muscles, the former raising and drawing the outer angle of the scapula to the midline and the latter carrying the inferior angle of the scapula in the opposite direction. Internal rotation is produced mainly by the subscapularis and to a lesser extent by the pectoralis major, latissimus dorsi and teres major muscles. External rotation is produced by the supraspinatus, infraspinatus, and teres minor muscles.

OPTIMUM FUNCTIONAL POSITION OF THE SHOULDER

When the shoulder-joint becomes ankylosed, very little functional disability will result, provided that the humerus is fixed to the scapula in the position of optimum function. This position is with the arm abducted 55 degrees and with enough forward flexion to bring the elbow in the same vertical plane as the anterior surface of the chest, and rotated out-

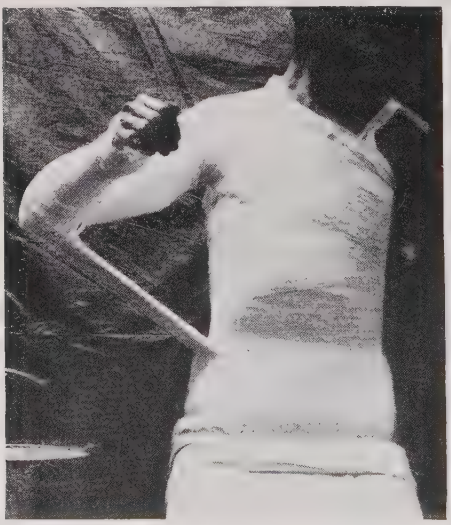
71

72

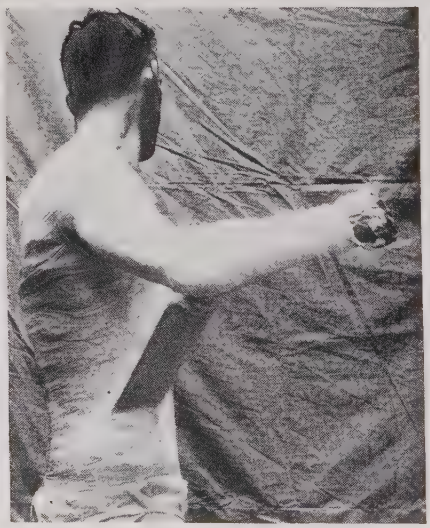
FIGS. 71 and 72.—Development of the epiphyses of the upper end of the humerus. (71) Roentgenogram at age of two years. (72) Roentgenogram at age of seven years, five months.

wardly about 15 degrees from the horizontal plane of the body, sufficient to cause the hand to be carried directly to the mouth when the elbow is flexed (see Fig. 73). The mobility of the scapula permits the arm to

FIG. 73.—Optimum functional position of the shoulder in case of ankylosis. Abduction 55 degrees; slight forward flexion; external rotation 15 degrees.



74



75

FIGS. 74 and 75.—Plaster jacket combined with casing of the arm and shoulder holding the arm in optimum position for function.

be dropped to the side, while contraction of the scapular muscles causes it to be elevated.

Abduction is also the position from which the earliest restoration of function is obtained following immobilization. The muscles causing

abduction do not become stretched, and preserve their power, while adduction is a movement easily recovered, because of the influence of gravity. This is an important consideration, as will be pointed out in discussing the treatment of injuries in this region.

I. DISLOCATIONS OF THE SHOULDER

The shoulder is more frequently dislocated than any other joint in the body, owing to the weakness of its structural arrangement, its exposed position, and the long leverage provided by the shaft of the humerus. The mobility of the shoulder girdle and the ease with which the clavicle may be fractured explain why dislocation of the shoulder is not more frequent. It is when the muscles are taken off their guard by sudden violence, or when coördination of the muscles is lost, as in epileptic seizures, that dislocation of the shoulder is apt to occur. It is met with usually in adult males, the nature of whose employment exposes them to injury, and in elderly women.

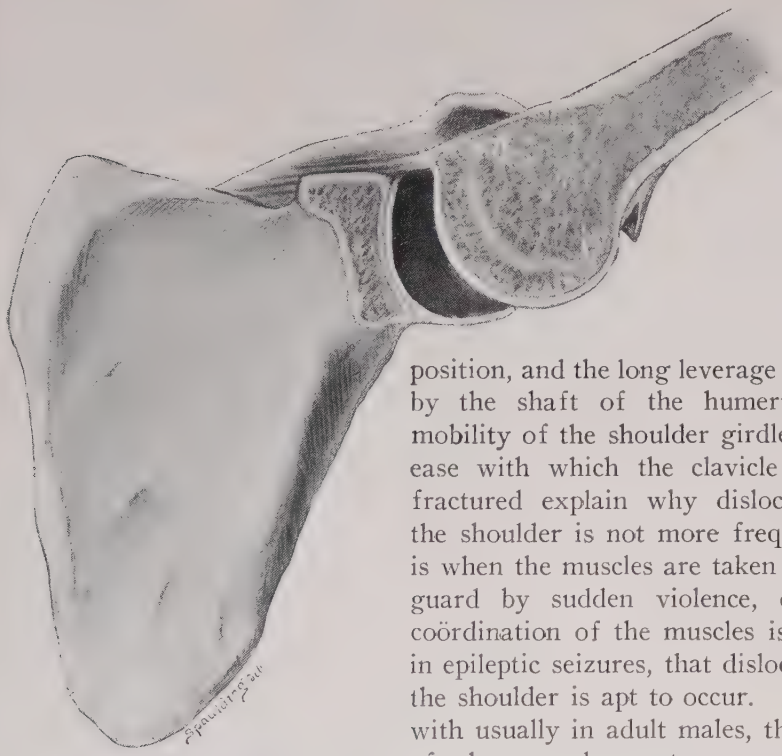


FIG. 76.—Mechanism of dislocation of the shoulder by hyperabduction.

Causation.—In the downward and forward varieties of dislocation, the upper arm is usually abducted at the time of the injury, which takes the form of a fall on the outstretched hand or elbow, forcing the arm into hyperabduction (Fig. 76). Dislocation may also follow from muscular action alone, or from a direct blow on the upper end of the humerus. Backward dislocation is caused by a blow on the flexed elbow, the arm being adducted, internally rotated, and slightly flexed, thus driving the head of the humerus through the posterior part of the capsule.

MECHANISM AND VARIETIES OF DISLOCATION OF THE SHOULDER

I. ANTERIOR DISLOCATION OF THE SHOULDER

When the arm is hyperabducted, the acromion process acts as a fulcrum by means of which the head of the humerus is brought to bear upon the infero-mesial aspect of the capsule of the shoulder-joint. This is the weakest part of the capsule, the only point not reinforced by muscular or tendinous structures, and it is easily ruptured, with resulting exit of the head of the bone from the joint cavity.

1. Sub-glenoid Dislocation

The head comes then to occupy the so-called sub-glenoid position between the long head of the triceps behind and the subscapularis in front. The rounded head of the humerus rests against the sharp edge of the axillary border of the scapula just below the glenoid cavity, and the arm remains abducted. This constitutes an unstable position and only rarely does the displacement cease at this stage. When it does, it is known as the sub-glenoid dislocation, or *"luxatio erecta."*

2. Subcoracoid Dislocation

Partly from muscular contraction, but chiefly due to the influence of gravity upon the abducted arm and the tendency of the head of the bone to find a more stable position, the latter leaves its sub-glenoid position and travels upward, inward, and forward to take up a position beneath the coracoid process, where it lies upon the anterior surface of the neck of the scapula beneath the origins of the coraco-brachialis and short head of the biceps muscles arising from the coracoid process (Fig. 77). The posterior part of the capsule is stretched across the glenoid, and the humerus is rotated laterally from stretching of the teres minor and infraspinatus muscles. The greater tuberosity is sometimes avulsed, forming later a bony obstacle to reduction, and allowing the long tendon of the biceps to slip out of the groove laterally. The axillary nerve may be bruised as it lies in the quadrilateral space.

3. Sub-clavicular Dislocation

This represents a further stage of the preceding, when the head travels further inwards against the edge of the clavicle. The head of the humerus comes to lie beneath the pectoralis minor, and the tuberosities are usually either torn off, or the tendons attached to them are ruptured.

II. POSTERIOR DISLOCATION OF THE SHOULDER

In the posterior type of dislocation of the shoulder, the head of the humerus is forced through the posterior part of the capsule into the infraspinous fossa, constituting the subspinous variety of dislocation. The subscapularis may or may not be ruptured, and in the latter case, it causes mesial rotation of the shoulder.

Diagnosis.— Dislocation of the shoulder is attended by a considerable degree of shock and often by intense pain from pressure on nerve trunks. The patient supports the flexed elbow with the hand of the sound side and tilts the head to the affected side.

The physical signs in the anterior type of dislocation follow naturally the altered anatomical relationships. The shoulder is noticeably flattened

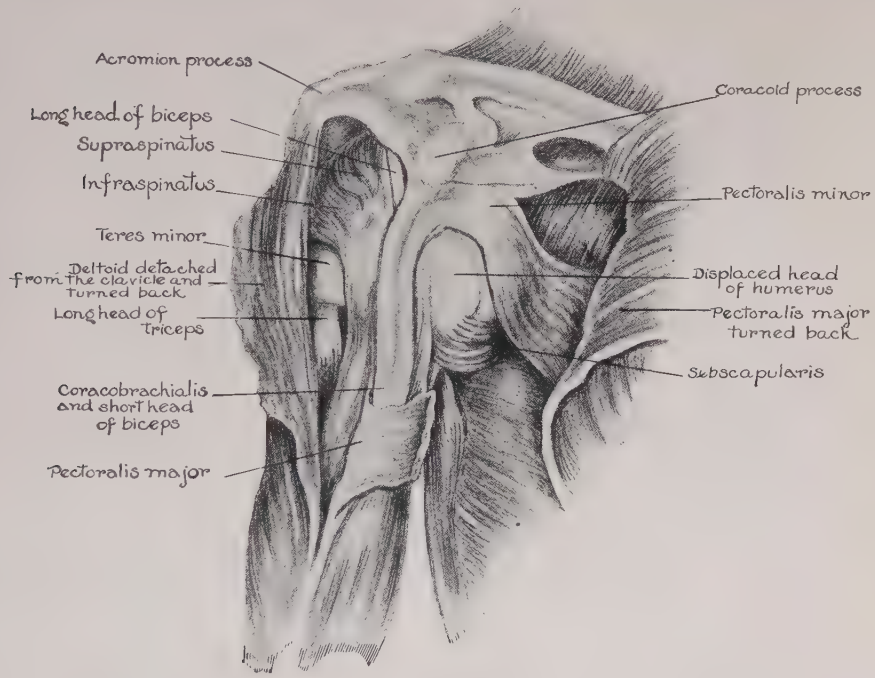


FIG. 77.—Anterior dislocation. Dissected specimen showing abnormal relation. (Piersol: Human Anatomy.)

from the absence of the head and tuberosities from their normal position (Fig. 78). On palpation, the outer edge of the acromion process is prominent, with a distinct depression beneath it, so that a straight edge may be made to touch the tip of the acromion and the lateral epicondyle of the humerus. All the muscles in the neighborhood are rigid and in spasm, and the axillary folds are lowered, with increase in the vertical circumference of the shoulder. The tension of the deltoid and biceps muscles results in slight abduction of the upper arm and flexion of the forearm. In certain cases, it may be possible to palpate the empty glenoid and the displaced head. When the hand is placed on the opposite shoulder, the elbow cannot be made to touch the chest wall (Dugas's sign). This sign is not always present in subcoracoid dislocations. Measurements of the upper arm are not of diagnostic importance.

In the posterior variety of dislocation, the physical signs are less characteristic, the features of importance being the broadening of the shoulder and palpation of the head in its new position. There is distinct

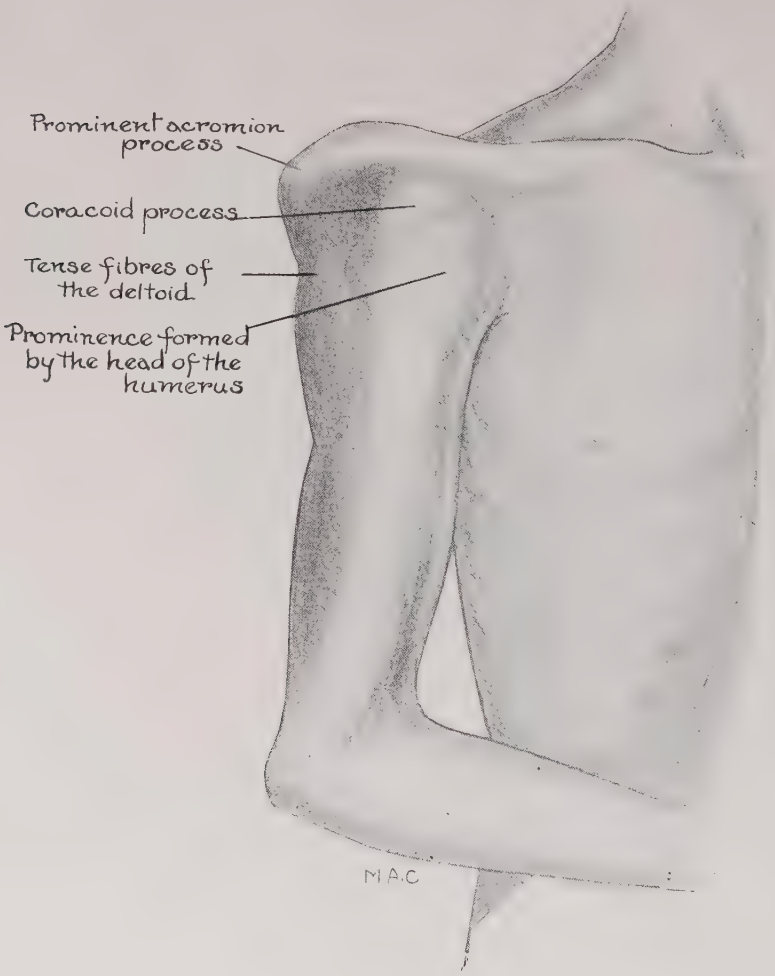


FIG. 78.—Anterior dislocation of the shoulder. Sketch showing the typical deformity. Note prominence of the head of the humerus and the hollow where the head should be.

hollowing of the shoulder in front, the arm is held by the side, and the elbow projects forward.

In the section upon fracture of the scapula, the differentiation of dislocation of the shoulder from fracture of the surgical neck of the scapula is considered. The other condition with which it is likely to be confused is dislocation of the shoulder plus fracture of the upper end of the humerus, a diagnosis of dislocation alone being made and the associated

fracture overlooked. Careful examination should reveal that in addition to the dislocation, abnormal mobility and crepitus are present, and that the displaced head does not move with the rest of the bone. Swelling is usually greater than in uncomplicated dislocation, and the upper arm

FIG. 79.—Roentgenogram of subcoracoid dislocation of shoulder. (Fracture Service, M. G. H.)

is shortened. Roentgenologic examination will differentiate the three conditions.

Treatment.— As a rule, reduction should not be attempted without an anæsthetic, except when the case is seen immediately after injury, or when it is one of recurrent dislocation. In all methods of reduction, the scapula must be fixed either by the hands of an assistant or by a broad sheet passed around the trunk, high in the axilla, in order that leverage exerted upon the humerus may be effective. The underlying principle is to disentangle the head from its new relations, and to cause it to retrace the path by which it left the socket.

Kocher's Method of Reduction.— This is an indirect method of reduction, by leverage, and is especially applicable to the anterior dislocations. The procedure is as follows (see Figs. 80, 81, 82):

82

81

80

FIGS. 80, 81 and 82.—Kocher's method of reduction. (80) Elbow is flexed to a right angle and pressed in toward the side. Humerus is then externally rotated. (81) Maintaining the external rotation, the elbow is carried inward and upward, across the front of the chest to the mid-line. (82) The arm is internally rotated and the hand of the injured limb placed on the opposite shoulder.

1. The elbow is flexed to a right angle and pressed in towards the side. This relaxes the biceps which otherwise would interfere considerably with reduction.

2. Grasping the arm by the wrist and elbow, the surgeon externally rotates the humerus as far as possible. This brings the head of the humerus opposite the opening in the capsule and causes it to gape.

3. Maintaining the external rotation, the elbow is now carried inward and upward across the front of the chest to the mid-line. During this movement, the head of the bone passes in the reverse direction toward the glenoid cavity, the surgical neck furnishing the fulcrum.

4. By a quick movement, the arm is now internally rotated, and the hand of the injured limb placed on the opposite shoulder. This frees the head from the edge of the glenoid and allows it to re-enter the socket.

This method is very effective, and in uncomplicated cases is generally the preferred method. Reduction may occur during any stage of the procedure and, as a matter of fact, usually takes place before the fourth step is reached.

Traction Method.—The traditional method of reduction by traction on the arm, with the heel in the axilla, depends on sheer force and requires no special description.

This method has, however, been modified in a way to reduce its brutality, and the resulting procedure is very effective and particularly applicable in long-standing or complicated cases. The scapula is fixed, and counter-traction obtained by a folded sheet passed around the chest high in the axilla, the ends of the sheet being held by an assistant. A second folded sheet is then passed about the arm, as nearly as possible at the level of the shoulder. The operator now abducts the arm to an angle of about 70 degrees and exerts traction, at the same time making gentle movements of rotation, while a second assistant standing near the head of

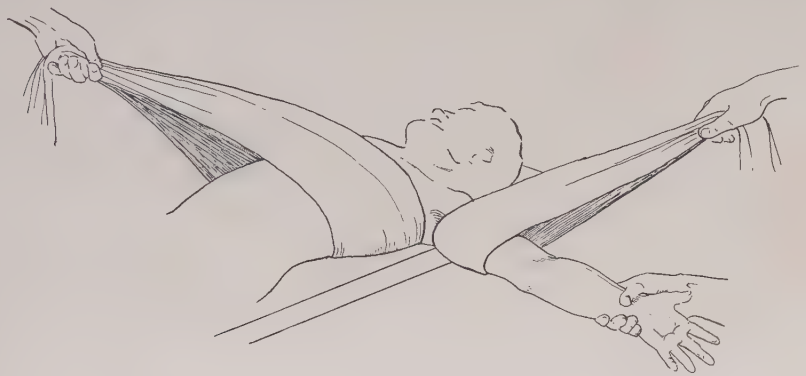


Fig. 83.—Traction method of reducing dislocation of the shoulder.

the table pulls steadily upon the sheet, encircling the upper end of the arm in a direction to carry the head into the socket (see Fig. 83). Direct traction brings the head opposite the opening in the capsule, and the upward traction causes it to enter the cavity.

After-treatment.—A cotton pad is placed in the axilla, the arm fixed to the side by a body bandage, and the elbow supported by a sling, the object being to permit healing of the torn capsule by immobilization of the joint. Before applying the first dressings, the shoulder should be gently but systematically massaged for fifteen minutes, and this should be repeated once or twice daily during the subsequent days of treatment. Supported active movements should be begun the day following injury and their range increased daily, keeping within the limits of pain. Prolonged immobilization is to be condemned, and at the end of a week the body bandage may be discarded and abduction and external rotation encouraged. At the end of four weeks, free use of the arm may be permitted.

Prognosis.— The possibility of damage to the axillary nerve, with atrophy of the deltoid, should be remembered. Also extensive injury and overstretching of the capsule of the shoulder-joint may be followed by

recurrent dislocation. The range of joint motion may subsequently be restricted from adhesions in the joint itself and in the subacromial bursa. Associated fractures of the greater tuberosity, unless accurately replaced, may permanently limit abduction.

RECURRENT DISLOCATION OF THE SHOULDER

Etiology.— Following an ordinary traumatic dislocation of the shoulder, particularly one in which the joint capsule has been extensively torn and the surrounding soft parts considerably injured, healing may result in permanent weakening of the joint. With this condition present, the dislocation may recur with only slight trauma, and when repeated several times may result in the condition of habitual recurrent dislocation.

This condition is of fairly frequent occurrence, and constitutes a serious disability. It is particularly apt to occur in epileptics, although it is encountered frequently enough in apparently normal individuals. The shoulder may be dislocated by the slightest movement, such as sneezing, turning in bed when asleep, or quick, unguarded movements of abduction of the arm.

Mechanism.— The etiological factor is more than a mere weakened or relaxed condition of the joint capsule. Incoördinated muscle action plays a large part. It has been pointed out that the function of the inner cone of muscles of the shoulder-joint, and particularly of the supraspinatus, is to hold the head of the humerus in the glenoid during the movement of abduction. The deltoid is inserted so far down the shaft of the humerus that its action in elevating the arm would tend to lever the head of the bone out through the inferior portion of the joint unless it is thus supported. In quick, unguarded movements, or in the spasm of sneezing and similar conditions, this team play of the muscles may be upset, and if the capsule is already weakened from previous injury, dislocation may be readily produced without the intervention of external trauma in any form.

In connection with factors predisposing to dislocation, Goldthwait's [1] observations concerning the influence of faulty body posture are of interest. When an individual stands with the shoulders drooped, the head of the humerus swings forward and inward to take up a position in close relation to the coracoid process. When the arm is abducted, actual impingement of the bones may occur, and additional possibilities of dislocation by leverage are presented.

Treatment.— The condition may be treated along conservative or radical lines. The time-honored conservative method is to hitch the arm to the side by means of a leather strap connecting a cuff about the upper arm to a belt encircling the chest (Fig. 84). By means of this the dangerous movement of abduction may be limited to any degree. Goldthwait

[1] J. E. Goldthwait, *Journ. Orth. Surg.*, April, 1908.

draws the shoulders back by means of a brace with shoulder straps, and corrects the postural defect. Both of these measures, either singly or combined, are fairly effective. If recurrence of the dislocation can be prevented for a long period, stability is finally acquired by natural means, and the use of apparatus may be discontinued.

Operative treatment has been brought into disrepute by the very general failure of the old method of plicating the capsule. In the Clairmont [2] operation, however, we now have a procedure which thus far has given very excellent results and justifies the most hopeful expectations for the future. A flap of muscle with intact nerve supply is split from the posterior border of the deltoid and detached from its humeral insertion. This is passed through the quadrilateral space, under the joint capsule, and sutured at the front of the axilla either to the humerus or coracoid process. The merit of this procedure lies in the fact that it utilizes the muscle which produces the dislocation to protect the joint. When the arm is abducted the transplanted flap contracts and not only reinforces the capsule, but slings the head upward.

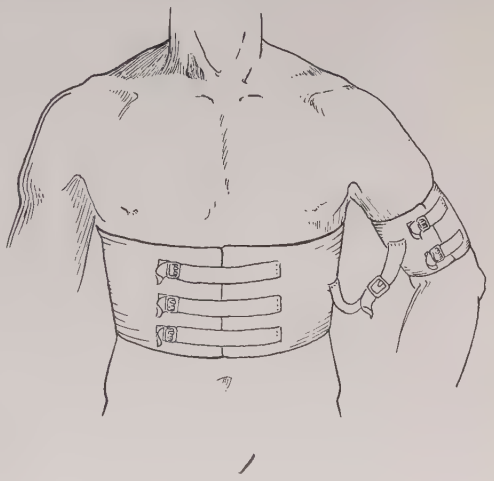


FIG. 84.—Brace for recurrent dislocation of the shoulder.

Bankart [3] reports several cases of recurrent dislocation where, at operation, the lesion was found to represent a tearing-loose of the attachment of the capsule of the shoulder-joint to the anterior lip of the glenoid cavity. Successful results were obtained in all, with good function, following operative repair of the defect. He considers that careful analysis of the mode of production of the recurring dislocation shows that it follows upon direct violence applied to the head of the bone from behind, driving it forcibly forward and so tearing off the capsular attachment to the anterior lip of the glenoid by arrachement.

OLD-STANDING DISLOCATION

It is generally conceded that it is exceptional to reduce an old-standing dislocation of two months or over, but individual cases vary a great deal, and it is a favorable feature if the head is movable and not fixed and if there is absence of complications such as associated fracture of the

[2] P. Clairmont and W. Ehrlich, *Arch. f. Klin. Chir.*, 1909, Vol. 89, No. 3.
[3] A. S. Bankart, *British Medical Journal*, December 15, 1923.

neck or tuberosities. The dangers of the manipulation are fracture of the neck of the humerus and tearing of the axillary vein. After adhesions are gently broken down, if the reduction cannot be effected by gentle manipulation, the attempt should be abandoned. Sometimes a second manipulation after a few days may succeed. If the disability is serious

FIG. 85.—Specimen from case of long-standing unreduced dislocation of shoulder. Note the atrophy of the glenoid and the development of a false joint surface between the coracoid and the head of the humerus. (Warren Anatomical Museum.)

and the patient's age and general condition are in favor of it, open operative reduction should be attempted through the anterior route. Under certain circumstances, resection of the head of the bone or osteotomy of the shaft may be necessary to restore function or to improve position. When the resection removes more than the articular portion, the results are not good functionally.

DISLOCATION ASSOCIATED WITH FRACTURE

The number of such cases is comparatively small, and the usual cause of the injury is a fall directly upon the shoulder. Fracture usually takes place through the surgical neck and tuberosities, and apparently

follows the dislocation through the continuance of the original force. The dislocation is usually of the forward type. The short upper fragment is frequently tilted upside down and lies to the inner side of the lower fragment, usually in the subcoracoid position (Fig. 87). The differentiation of this condition from fracture of the surgical neck

FIG. 86.—Fracture dislocation of shoulder. Anterior type of dislocation with the greater tuberosity fractured apparently from contact with the glenoid. (Fracture Service, M. G. H.)

of the scapula and uncomplicated dislocation has already been considered. There remains only to emphasize the two positive signs: namely, the absence of the head from the glenoid cavity, and its failure to rotate and move with the shaft of the humerus. The lesion is a serious one from the point of view of reduction, as the presence of the fracture prevents the surgeon from utilizing the leverage of the shaft of the humerus, and unless reduction is effected, the function of the joint is very seriously impaired. The callus of the fracture is apt to exert very painful pressure upon the brachial nerves.

Treatment.— Under anæsthesia, an attempt at reduction of the dislocation should be made by traction upon the abducted shaft, combined

with local manipulation of the displaced fragment. Should the attempt be unsuccessful, the best course is to expose the affected region by operation and so attempt the restoration of the head. Even then this may be very difficult, and great assistance is obtained by employing bone elevators or McBurney's hook to lever and control the short upper fragment.

FIG. 87.—Fracture dislocation. Roentgenogram showing how the head has been dislocated and turned upside down. (Fracture Service, M. G. H.)

When the head has been returned to the glenoid, advantage may be taken of the operative exposure to reduce the fracture and secure alignment by some method of internal fixation. The wound is then closed in layers and the limb put up in an abduction plaster cast, access being obtained to the arm and shoulder by valving the cast for this purpose (Fig. 88). Massage and passive motion should be started early.

The surgeon should be particularly warned against excision of the upper fragment. This is an easy procedure and often seems desirable as an alternative to proceeding with the operative reduction, which is difficult and time-consuming. Nevertheless, the functional results are bad. Excision of more than the articular surface of the head destroys

the function of the muscles attached to the tuberosities and results in a weak, flail shoulder.

Finally, the course of allowing the fracture to unite before attempting to reduce the dislocation is to be condemned, as it results either in failure to reduce the dislocation or in refracture in the attempt to do so.

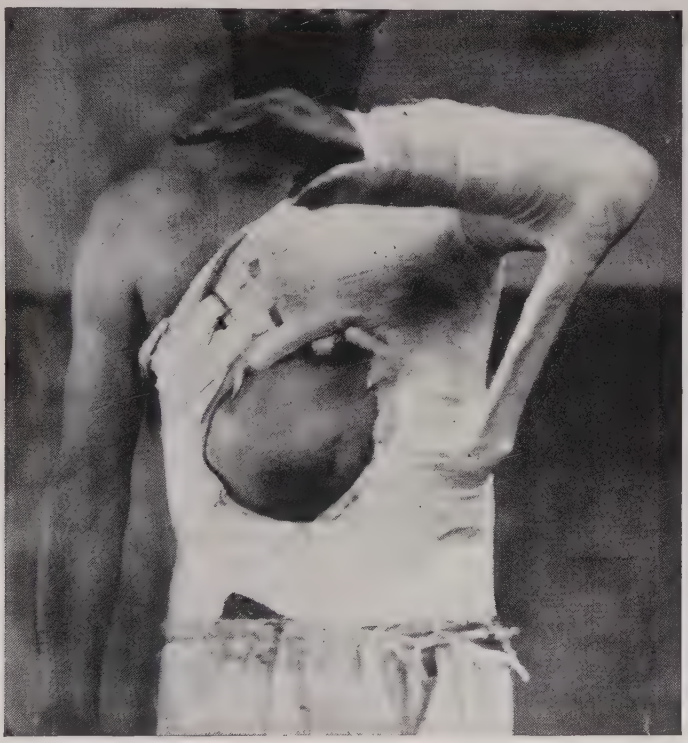


FIG. 88.—Plaster shoulder spica and jacket.

II. INJURIES OF THE UPPER END OF HUMERUS

General Considerations.— Four typical injuries occur in the region of the upper end of the humerus:

I. FRACTURE OF THE SURGICAL NECK
II. SEPARATION OF THE UPPER HUMERAL EPIPHYSIS
III. FRACTURE OF THE ANATOMICAL NECK
IV. FRACTURE OF THE TUBEROSITIES

Of these, the first three involve the entire diameter of the bone and occur in the same immediate vicinity, and it might be supposed that their treatment would be almost identical. However, this is not the case and, as will be seen, they represent entirely distinct types of injury.

Fracture of the surgical neck is an injury of adult life, separation of the epiphysis occurs in childhood or adolescence, while fracture of the

FIG. 89.—Specimen showing fracture of the surgical neck. (Warren Anatomical Museum.)

anatomical neck is typically an old-age fracture. Fracture of the surgical neck requires treatment by continuous traction in the position of abduction. Separation of the epiphysis calls for manipulative reduction, and when anatomical replacement is obtained, immobilization by soft dressings alone is sufficient. As active movement in a child is quickly regained, efforts especially directed at early motion need not be stressed. In impacted fracture of the anatomical neck in elderly persons, active motion from the beginning is required, and the best functional results are usually obtained without immobilization or reduction.

I. FRACTURE OF THE SURGICAL NECK

Etiology.— The surgical neck of the humerus is the most common site of fracture in the upper end of the humerus. It includes that part of the bone lying between the epiphyseal line and the point of attachment of the pectoralis major and teres major muscles (see Fig. 91). It is particularly liable to injury on account of its constricted shape, its lack of support from muscles or tendons, and its situation at the end of the long lever provided by the humerus.

Fracture of the surgical neck may occur at any age, but is most frequently encountered in young and middle-aged adults. In young persons the fracture is frequently incomplete or subperiosteal. Complete fractures are usually transverse, seldom comminuted, and not often impacted. They may or may not be accompanied by displacement.

The injury may be produced by a fall on the elbow or hand, with the arm in abduction and fixed by the muscles inserted into the tuberosities (Figs. 92, 93). The surgical neck then represents the area of greatest strain. The fracture may also follow severe and unguarded muscular action but more frequently results from a direct blow.

Displacement.— In cases of displaced fracture, the deformity is classical. The upper fragment is almost constantly tilted upward laterally or abducted from the pull of the muscles inserted into the greater tuberosity, particularly the supraspinatus (Fig. 94).

Rotational displacement is not common, the tendency to external rotation exerted by the muscles inserted into the greater tuberosity being counterbalanced by the action of the subscapularis attached to the lesser tuberosity. Transverse fractures show least tendency towards displacement, and oblique fractures the greatest. The position of abduction assumed by the upper fragment in certain cases of incomplete fracture by indirect violence is due to the fact that the force is exerted on the outside of the arm in the abducted position of the limb, the shaft being forced down to the side against the resistance of the muscles attached to the greater tuberosity. This produces an outward angulation at the site of fracture.

In complete fracture, the distal fragment or shaft is usually displaced into the axilla,—that is, mesially and upward. This is partly due to the pull of the pectoralis major and latissimus dorsi muscles, but chiefly is the result of the temporary continuation of the original fracturing force. There is over-riding of the fragments and shortening.

FIG. 96.—Unreduced fracture dislocation of the neck of the humerus. The head is rotated forward but still lies in the glenoid, and the shaft has been driving beneath the acromion process. Army Medical Museum.

Diagnosis.— In addition to the usual signs of fracture, such as loss of the use of the arm and swelling, there is deformity both by inspection and palpation. The rounded appearance of the shoulder is preserved, but there is an unusual concavity or hollowing in the lateral outline of the arm, a little distance below the acromion (Fig. 98) in contrast to dislocation

of the shoulder where the rotundity of the shoulder is lost. The head of the humerus may be felt in the glenoid cavity, and by grasping the head and tuberosities and gently rotating the shaft, abnormal mobility and crepitus may be detected. When ecchymosis appears, it first makes itself evident in the front of the arm in the line of the long tendon of the biceps, the path of least resistance being in the line of cleavage between

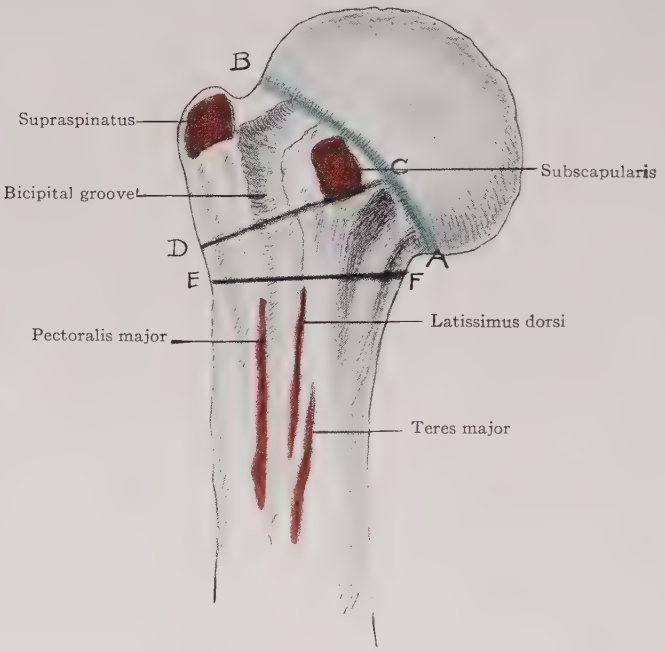


FIG. 91.—Upper end of the humerus. A-C-B represents the line of capsular attachment, and corresponds to the anatomical neck. A-C-D represents the line of epiphyseal junction. E-F represents the surgical neck.

the deltoid and pectoralis major. Such an ecchymosis is almost pathognomonic of an injury to the upper end of the humerus.

In cases of incomplete fracture, the local evidence will consist chiefly of sharply localized tenderness over the fracture site, unusual bony thickening about the humeral neck, and limitation of motion most marked in abduction. Demonstration of shortening by measurement will be a valuable aid in making the diagnosis. Measurement is best made from the angle of the acromion to the tip of the external epicondyle of the humerus.

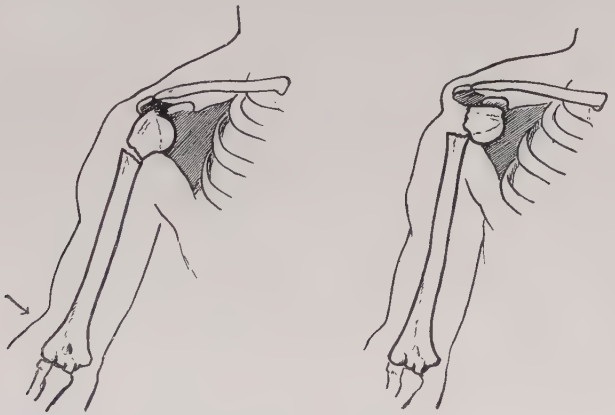
Roentgenologic Examination.—The final diagnosis can be made only after inspection of a radiogram, particularly in cases where the fracture is incomplete or impacted. The examination by X-ray should be made before and after the treatment of the fracture. Two views are recommended: namely, one taken in the antero-posterior plane, and a second view with

the arm abducted, the tube in the axilla, and the plate on top of the shoulder, to demonstrate the amount of antero-posterior displacement. If, after treatment, the position is found to be satisfactory, another plate need not be taken until the end of two or three weeks. If the position must be altered to secure correction of deformity, fresh exposures should be made until the position is shown to be satisfactory.

Treatment.— From the standpoint of treatment, it is important to divide cases of fracture of the surgical neck into two classes: displaced fractures, and fractures without displacement.

A. Fractures with Displacement

Indications.— The indications here are definite. The proximal fragment is too short and its muscular covering too thick to permit of its



FIGS. 92 and 93.—Fracture of the surgical neck of the humerus by indirect violence. (92) Drawing to represent the effect of violence applied to the abducted arm, operating against the resistance of the muscles inserted in the greater tuberosity. (93) The resultant displacement.

position being altered from without. Alignment can be corrected only by lifting the distal fragment and arm out and up until they are in the axis of the short abducted fragment (Fig. 99). The arm must be fixed in the abducted position, and over-riding prevented or corrected by traction.

Another important factor in determining the choice of position is that abduction constitutes the optimum position for restoration of function in injuries of the shoulder. Involvement of the joint and overlying muscles and bursæ by adhesions which follow the repair of the associated injury to the soft parts, combined with prolonged fixation, makes the recovery of motion difficult. The limitation of motion is commonly in the direction of abduction, the most useful motion of the shoulder. Recovery of motion from the abducted position is made more easy on account of the influence of gravity, and it can be ensured that the range of abduction will not be lost in bringing the arm down to the side. Further,

if stiffness of the joint does result, scapular motion will compensate for it to a large extent.

Reduction.— In cases of complete fracture, preliminary ether manipulation, consisting in traction on the abducted arm while the assistant

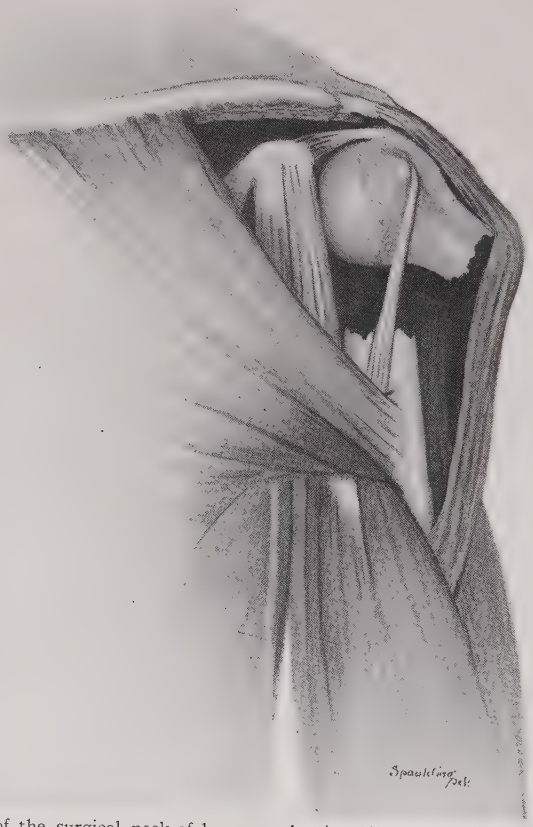


FIG. 94. Fracture of the surgical neck of humerus showing characteristic displacement. Note the abduction of the upper fragment and adduction of the lower fragment. Usually there is more shortening than indicated by the figure.

presses the proximal portion of the shaft outward, permits the two fragments to be guided into alignment where they can be held by proper splinting, and is a valuable first step.

In incomplete fracture with outward bowing or impaction, reduction is necessary to correct the deformity. The upper fragment is fixed against the acromion by abducting the arm. The scapula is then held down by an assistant, while the operator makes traction on the arm and hyperabducts. The assistant guards against dislocation of the shoulder by pressing up strongly against the head from the axilla. The acromion is thus used as the fulcrum against which the arm is straightened. The incom-

plete fracture is made complete, and the impacted fracture broken up. If done gently, displacement of the fragments need not be feared.

Fixation.— The fracture being reduced, the further treatment brings up the question as to whether the case can be satisfactorily handled while

FIG. 95.—Fracture of the surgical neck of the humerus with marked displacement. Anterior view. Note that the clavicle is also fractured at A.

ambulatory. There are many so-called "aeroplane" splints, intended to hold the arm in full abduction and external rotation; some are very ingenious and permit of traction and counter-traction. None of them, however, gives sufficiently complete fixation to meet the indications satisfactorily (see Figs. 114–119). Bed treatment not only increases the patient's

comfort but shortens the convalescence and usually leads to earlier restoration of function.

Thomas Arm Splint.—In all but very old patients, the method of choice will then be recumbency in bed, with special apparatus to provide traction

FIG. 96.—Roentgenogram made through the axilla in same case as Fig. 95, showing gross anterior displacement of the shaft.

in the abducted position. The most satisfactory all-round splint for this purpose is the Thomas arm splint (Fig. 100). It consists of a metal ring padded with felt and covered with leather, to which are fastened two metal bars the length of the arm and joined together at their ends.

The ring is slipped on over the arm and pulled up over the shoulder girdle, which it fixes by encircling the clavicle, acromion, and neck of the scapula, and resting firmly against the side of the thorax. This gives a fixed point for counter-traction (Fig. 101). The arm is supported in

the metal frame as in a gutter, resting on flannel slings passing across from bar to bar, and fixed with safety pins (Figs. 102, 103).

Fixed and Sliding Traction.—Traction is obtained in the usual manner with adhesive strips applied to the skin from the wrist to shoulder, or

FIG. 97.—Same case as Figs. 95 and 96, following reduction. Marked improvement in position but still considerable deformity. On account of patient's extreme age no further attempt at correction was made. (Fracture Service. M. G. H.)

strips of flannel fixed to the skin with glue (Figs. 104, 105, 106). The lateral and mesial aspects of the arm are used. Cords lead from the free ends of the strips distally over the hand, which is left free, and traction may be obtained by knotting them to the end of the splint and twisting them with a nail on the principle of the Spanish windlass, or, as is shown in the illustration, by means of weight and pulley traction. The latter method is preferable, as it gives an even, uniform pull and requires less attention. The amount of weight required is rarely more than ten pounds.

Suspension of Splint.— The apparatus must now be fixed or suspended. As a temporary measure, the end of the splint may be fastened to the back of a chair set out from the side of the bed. A portable Balkan frame

will allow proper suspension, or, if it is lacking, two wooden uprights may be set up at the head and foot of the bed about seven or eight feet in height to support a crossbar lengthwise over the bed. The splint is then suspended by means of cords leading from the upper and lower ends of the splint over pulleys fastened to the overhead beam and counterbalanced by sufficient weight to allow the splint to rise or fall as the patient raises or lowers himself in bed (Figs. 107, 108, 109).

A loop of cord should always be provided, hanging from the overhead bar to give a hand grip for the unaffected arm. Freedom of the

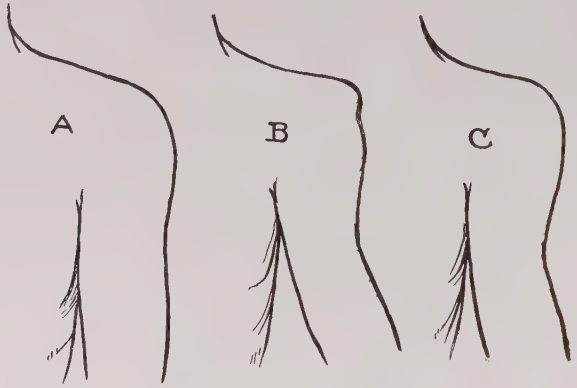


FIG. 98 (A, B, C).—Changes in the outline of the shoulder. (A) Normal. (B) Dislocation of the shoulder. (C) Fracture of the surgical neck.

patient to change position without help will be greatly facilitated by this measure.

Flexion of Elbow.—An alternate method of using the Thomas splint with the elbow flexed is shown in figures 110 and 111. In general, this method is to be preferred to the one previously described, as the position is more comfortable for the patient and better maintains the mobility of the elbow. When the latter is immobilized in extension for four to five weeks, contracture takes place and a certain amount of time is required before the movement of flexion is completely restored. The position of the fragments can generally be maintained as well with this method as with the first.

Before applying the splint, two sets of traction strips are applied, one to the upper arm and one to the forearm. The cords from the former are then fixed to the end of the splint according to either the fixed or sliding methods of obtaining traction. The elbow is then flexed, and the forearm suspended to an overhead pulley, and counterbalanced by a weight of a few pounds. The splint itself is also suspended to the overhead frame and counterpoised.

The advantages of the Thomas splint may be summed up by saying that it meets all the indications of treatment by providing integral trac-

tion and counter-traction in the fully abducted position, that it immobilizes the fracture-site, and at the same time affords comfort and freedom to the patient in bed and permits of his proper care.

After-treatment.— As the shoulder is left uncovered by the apparatus, massage may be begun at once. At the end of eighteen days, passive and

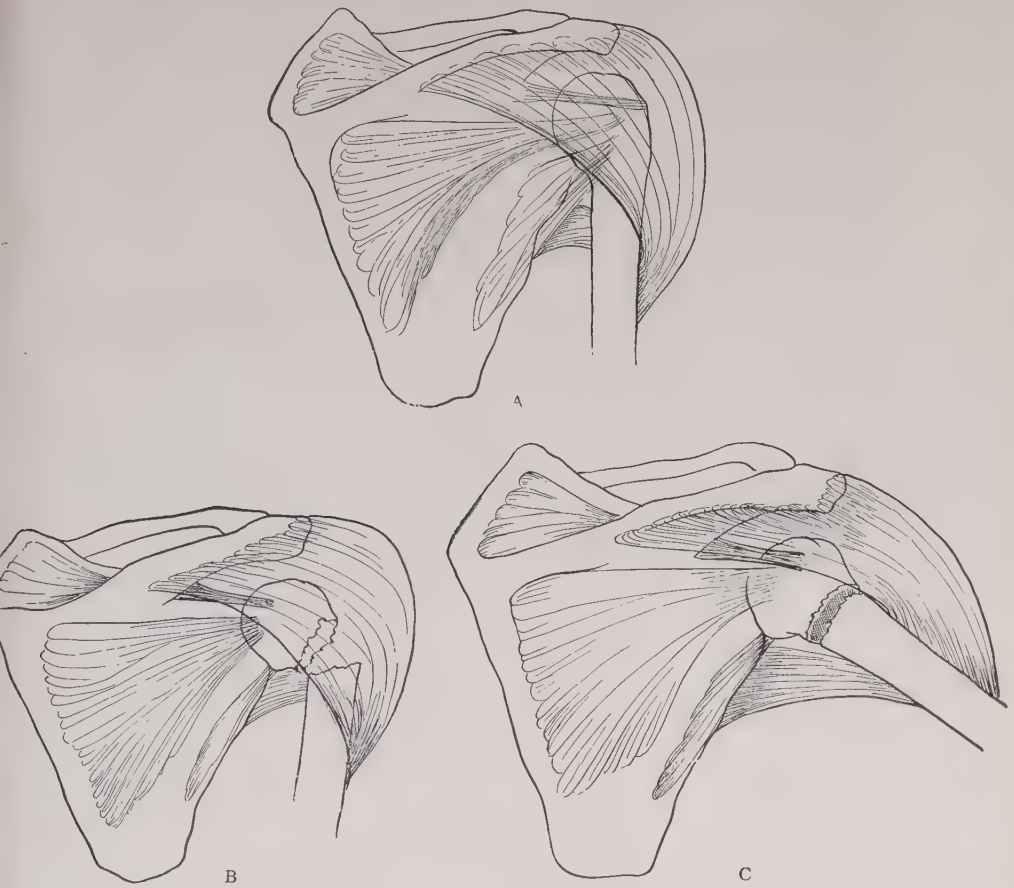


FIG. 99 (A. B. C).—Fracture of the surgical neck. (A) Showing muscles attached to the greater tuberosity. (B) Shows action of these muscles in causing abduction of the upper fragment in fracture of the surgical neck. (C) Correction obtained by lifting the long distal fragment upward and outward into proper relation with the head.

supported active motion is begun and employed daily, the traction cords being loosened for this purpose. Movements of rotation should be given particular attention, as they are apt to be limited.

Aeroplane Splint.— At the end of four or five weeks, union is usually sufficiently solid to permit of change to one of the ambulatory aeroplane splints, to be worn for about two weeks. In old and infirm patients, for whom recumbency is inadvisable from liability to pulmonary complica-

tions, the æroplane splint should be used from the beginning. The Cleary aeroplane splint is probably the most satisfactory type of ambulatory abduction apparatus (Figs. 114-118). It is mechanically correct because it gets its support from the side opposite the injury. It gives excellent fixation and is light and comfortable; it also permits of traction, if this is wanted. The splint is removed daily for gradually increasing periods, and during the sixth week is worn only at night. The arm is then carried

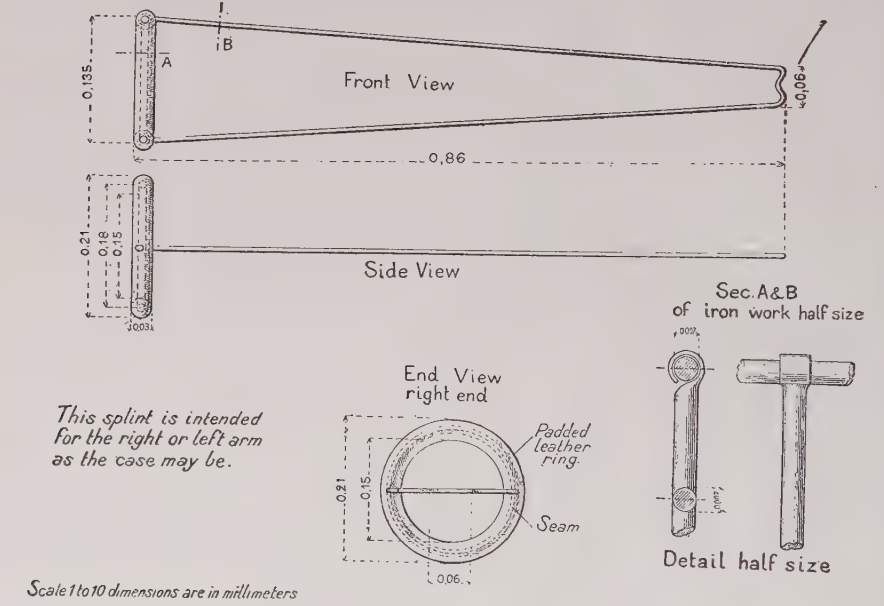


FIG. 100.—Mechanical drawing of Thomas arm splint. (U. S. Army Splint Manual.)

only in a sling during the day and removed at intervals for active exercise of the shoulder and elbow. All apparatus may be discontinued at the end of six to eight weeks from the time of fracture, but use should be restricted for two weeks longer.

B. Fracture without Displacement

Fractures of the surgical neck without displacement are fairly common among children, but rare in adults. They are usually either subperiosteal or incomplete, and there is little tendency towards loss of position. A sling to support the arm, an axillary cotton pad, and a body bandage to fix the arm firmly to the side are quite sufficient for immobilization. Massage and movement are employed from the beginning.

Prognosis.—Non-union is quite exceptional. Open reduction is sometimes necessary for correction of obstinate displacement. The best approach is by the anterior route. Internal fixation is seldom neces-

sary, the fragments being kept in position by traction on the arm during closure of the wound until a Thomas splint is applied.

II. SEPARATION OF THE UPPER HUMERAL EPIPHYSIS

The upper humeral epiphysis includes the head, tuberosities, and upper fourth of the intertubercular groove, and unites with the shaft about the twenty-first year. Its conical shape adds considerably to the natural resistance to displacement (Fig. 121).

Traumatic separation of the epiphysis is usually met with in boys between the ages of five and fifteen years from direct violence to the

FIG. 101.—Thomas arm splint showing method of obtaining counter-traction by ring resting against the chest wall.

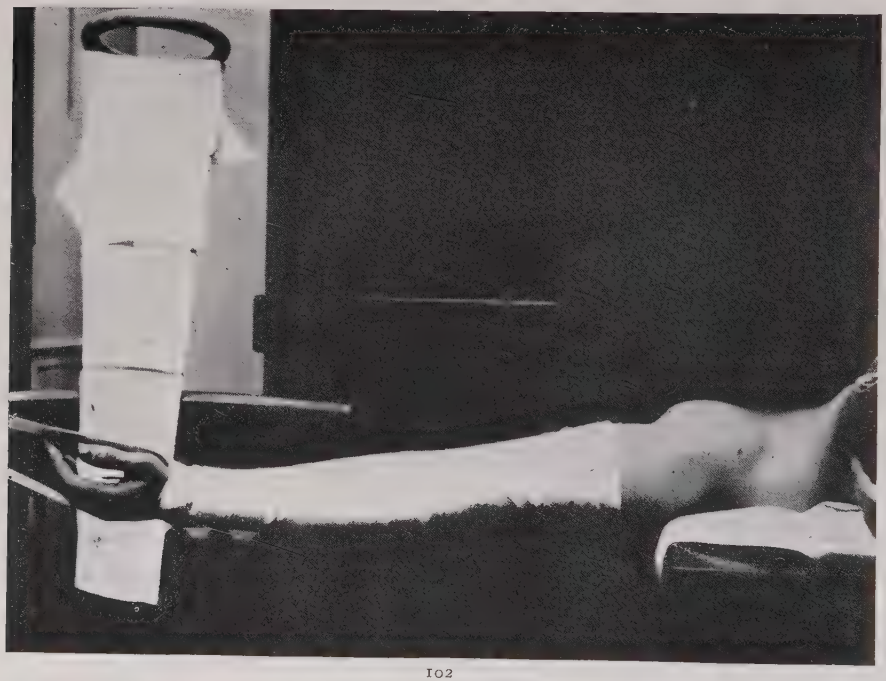
shoulder, a fall on the outer side of the elbow, or from strong traction combined with abduction and rotation of the limb, as in lifting a child by the arm.

Epiphyseal Strain.—The injury may take the form of a strain of the epiphysis or of a separation between it and the diaphysis without displacement. The diagnosis then rests upon the history, tenderness over the line of the epiphysis, sharply localized on pressure, loss of power to use the arm, and a radiogram showing a space between the epiphysis and diaphysis slightly wider than normal.

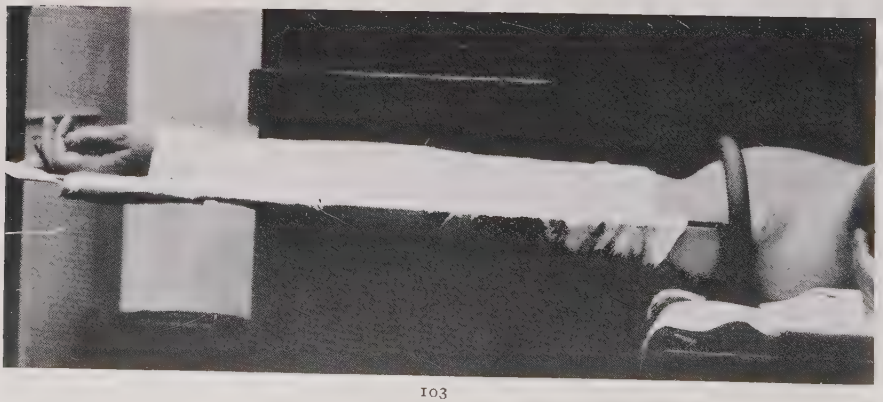
Displacement.— In other cases there may be displacement, complete or incomplete, controlled by the several factors that operate in fracture of the surgical neck of the humerus. The displacement is habitually of the shaft forward and to the inner side of the abducted upper fragment. In cases of partial displacement, the periosteum remains intact to a great extent.

Diagnosis.— When considerable displacement exists, the appearance is characteristic. The upper end of the shaft projects under the skin

in front of the shoulder, where it may both be seen and felt an inch or more below the acromion (Fig. 122). The age of the patient, the muf-



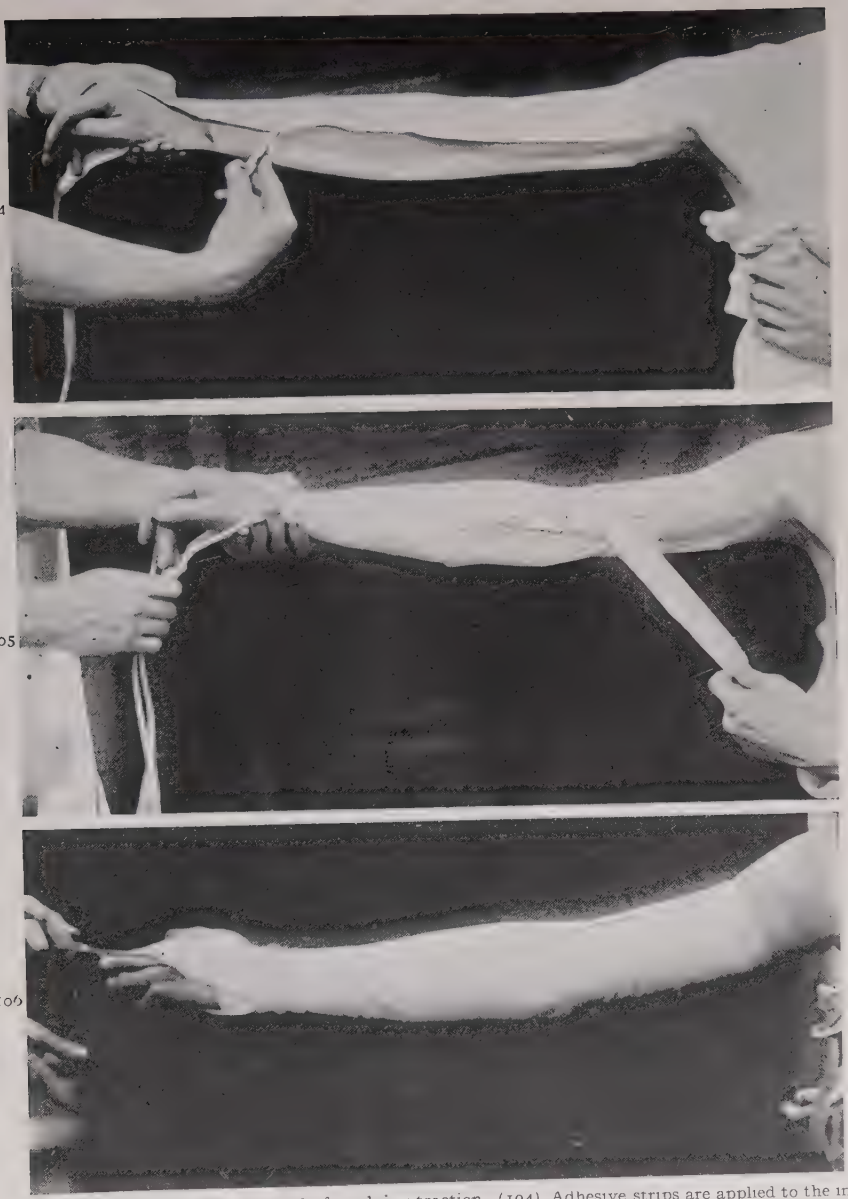
102



103

FIGS. 102 and 103.—Application of Thomas arm splint. (102) With the patient lying, the arm is supported in abduction while the splint which has previously been prepared with flannel slings is passed over the hand. (103) The ring is pulled up against the chest and the ends of the traction strips tied to the ends of the splint.

fled character of the crepitus, and the transverse line of the upper end of the diaphysis help to establish the diagnosis. At the same time it



FIGS. 104, 105 and 106.—Method of applying traction. (104) Adhesive strips are applied to the inner and outer sides of the arm. The edges are cut whenever necessary to eliminate wrinkles. (105) Additional fixation is secured by spiral turns of adhesive plaster. (106) A circular bandage is applied over all, fixing the adhesive in place.

will be noticed that the head of the humerus occupies its normal position in the glenoid cavity and does not move with the shaft.

Treatment.—The rule for treatment should be immediate reduction under general anæsthesia. With the arm abducted, steady traction is exerted, while an assistant presses the upper end of the shaft back into position. Sometimes it may be necessary to exert traction with the

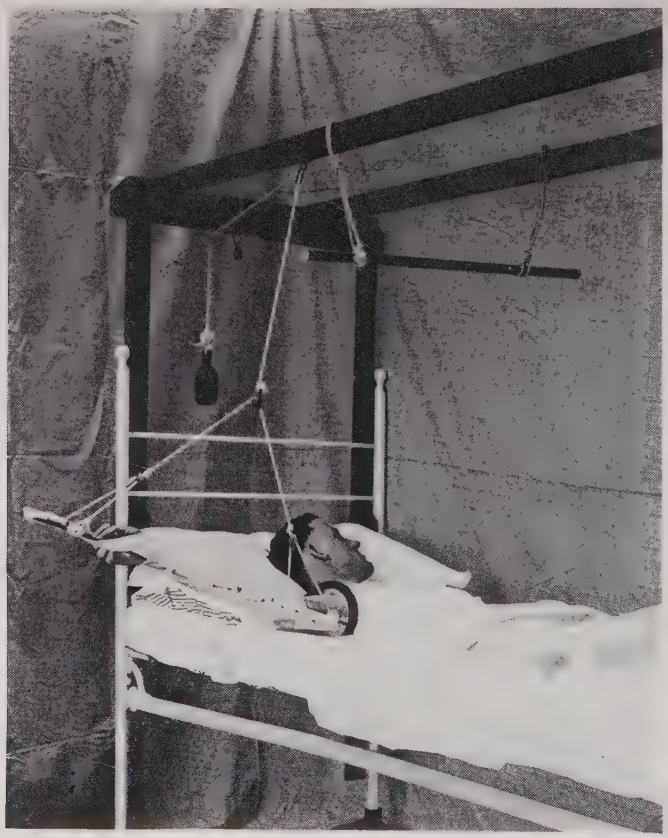
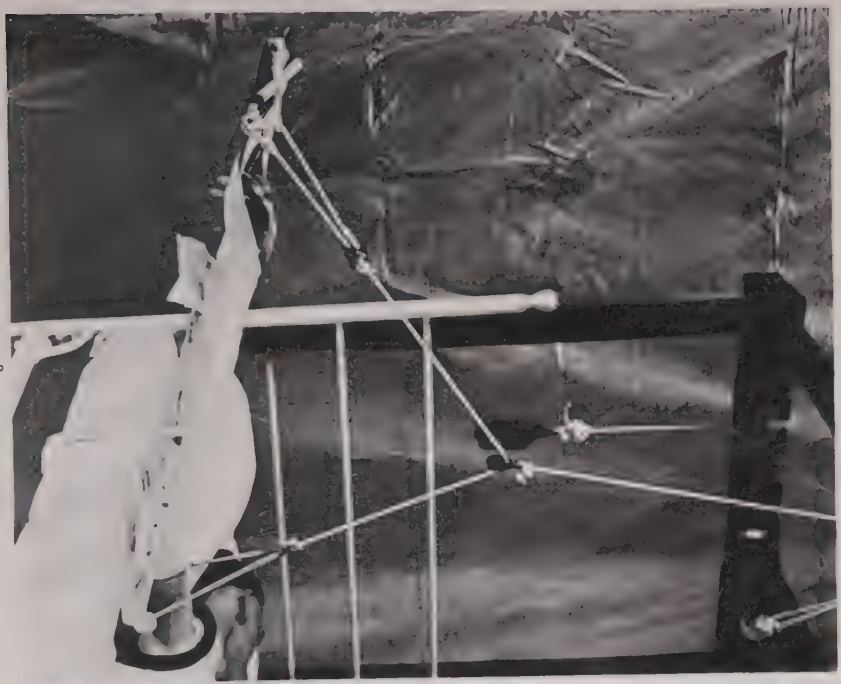


FIG. 107.—Suspension of the splint.

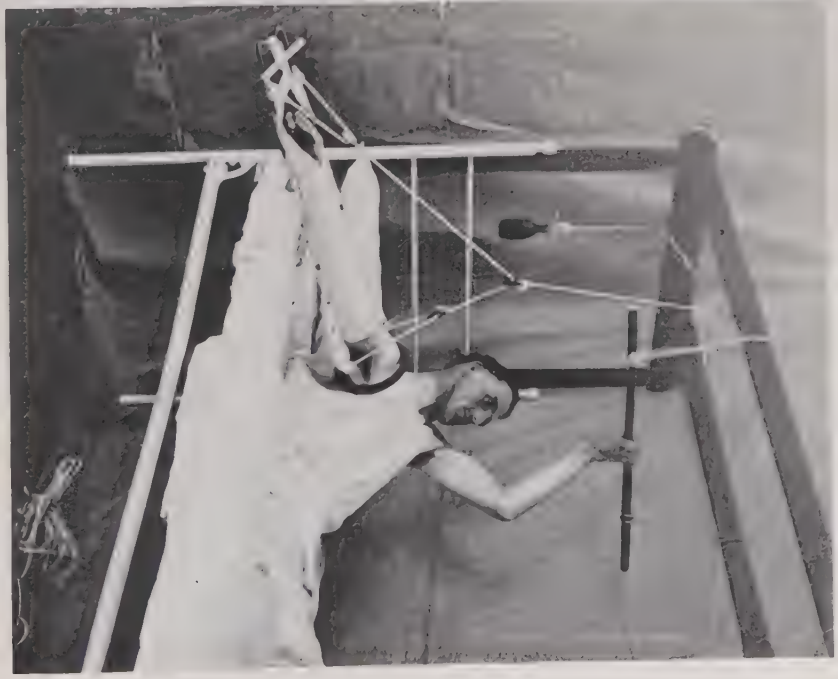
arm in the position of hyperabduction and flexion, in order to fix the small upper fragment by the tension of the posterior part of the capsule.

The limb is then immobilized for two to three weeks by means of a sling and body bandage (Figs. 123, 124), followed by a sling alone for ten days more. Massage is employed from the beginning. There is no tendency toward redisplacement, and limitation of motion of the shoulder is not to be feared in a child, so that immediate active motion is not required. Union results almost invariably, and the subsequent growth of the limb is seldom affected.

When complete replacement is not obtained by the primary manipu-

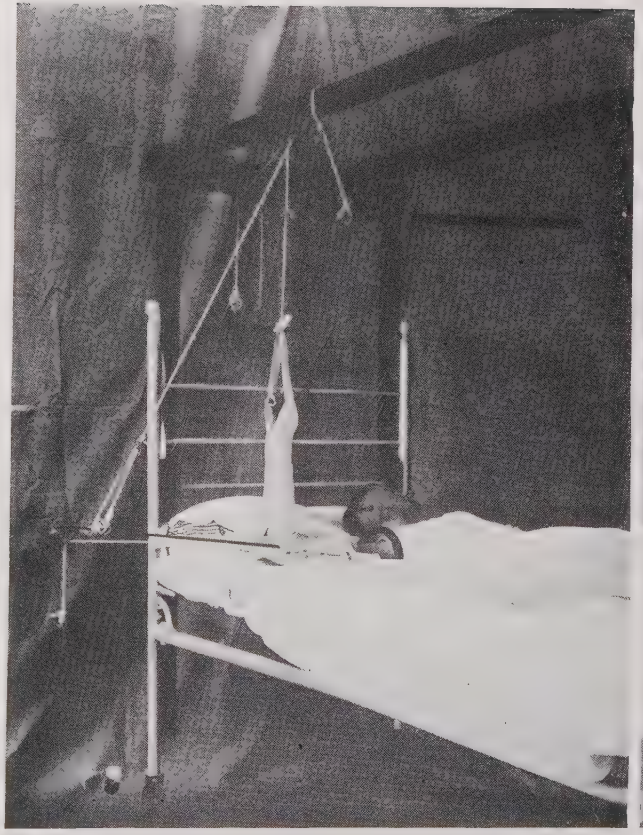


108

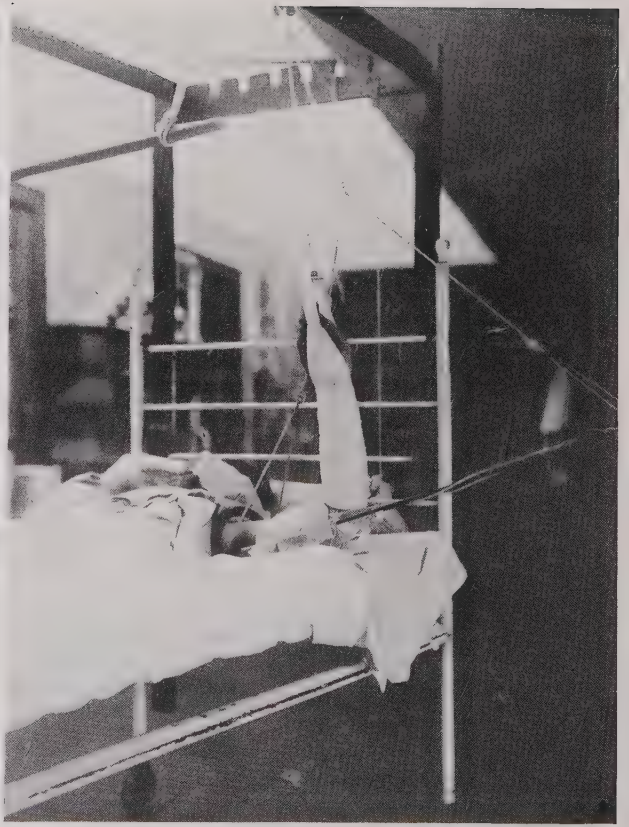


109

FIGS. 108 and 109.—(108) Suspension of the splint. (109) Shows the amount of movement made possible by the suspension of the splint.

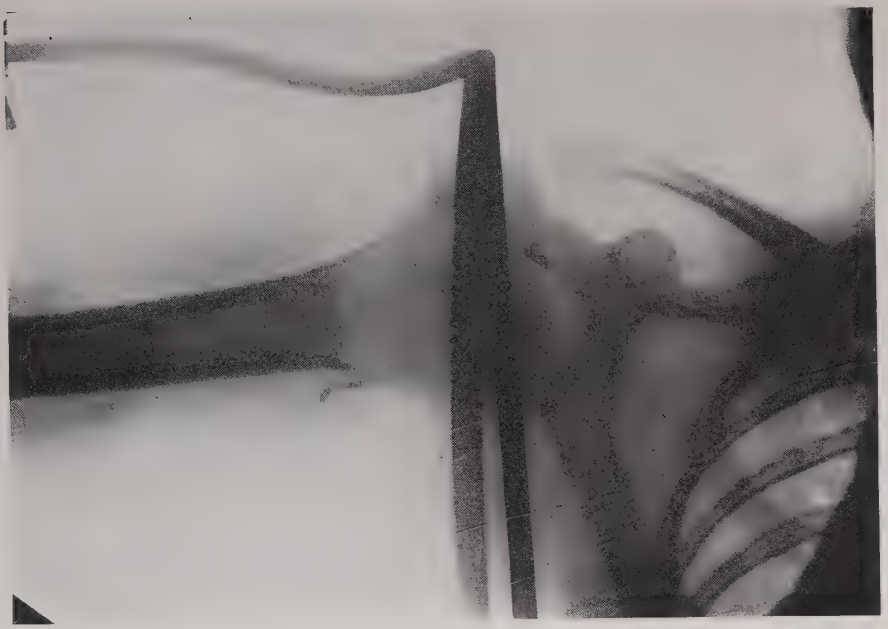


110

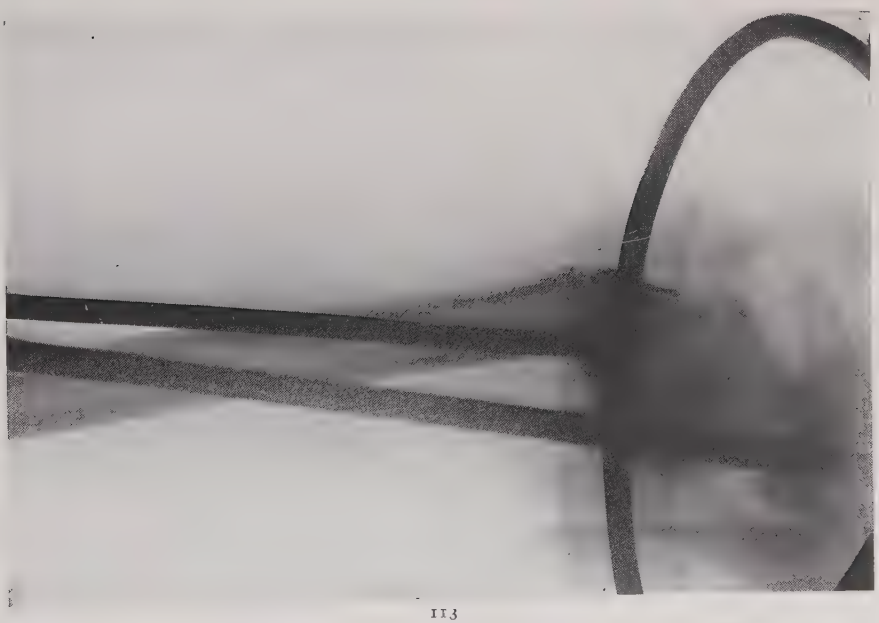


111

FIGS. 110 and 111.—Alternate method of applying Thomas arm splint. In this case, the elbow is flexed to a right angle and the forearm is suspended by traction strips from an overhead pulley. Traction is exerted on the upper arm as with the preceding method. The position is more comfortable than the straight one.



112



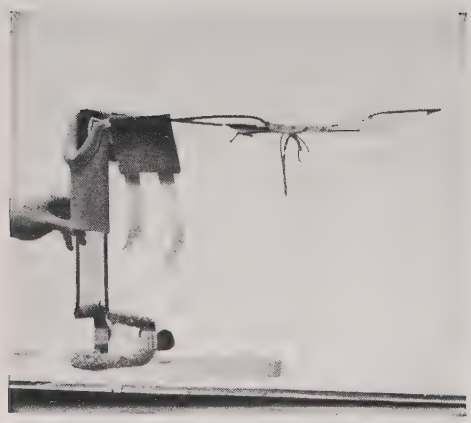
113

FIGS. 112 and 113—Roentgenograms of a fracture of the surgical neck treated in the Thomas arm splint. These views illustrate the necessity of making roentgenograms in the vertical as well as in the antero-posterior plane in fractures of the surgical neck. (112) Anterior view. Position is apparently excellent. (113) Axillary view. Well-marked anterior angulation. (Fracture Service, M. G. H.)

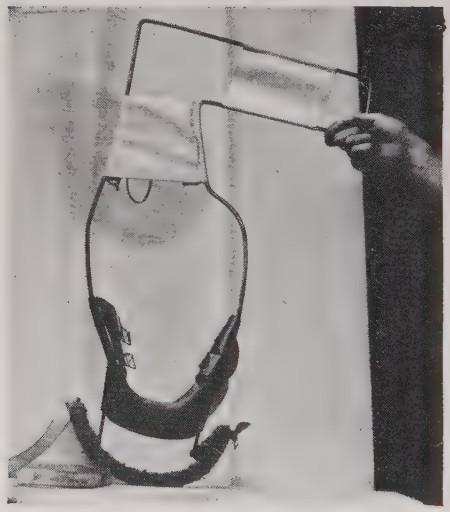
lation, or when a case with displacement is not seen until a few days after the injury, it is advisable to apply traction for a few days with the arm in abduction in a Thomas arm splint. The manipulation should then be repeated, and reduction will usually be obtained. Open reduction is rarely required and then only because of the interposition between the fragments of torn periosteum or other soft tissue.

III. FRACTURE OF THE ANATOMICAL NECK

Impacted fracture of the anatomical neck of the humerus is generally recognized as a type of old-age fracture. In this period of life, weaken-



114



115

FIGS. 114 and 115.—Cleary aeroplane splint. (114) Anterior view. (115) Viewed from above.

ing of the upper end of the humerus from bone atrophy is usual, and this portion is peculiarly exposed to violence from the impact of a fall on the shoulder or elbow, driving the upper end of the head into the cancellous bone of the upper end of the shaft. Associated fracture of the tuberosities without displacement is a frequent accompaniment.

Diagnosis.— The signs of bony injury are often slight and the surgeon should regard even an apparently trivial injury of the shoulder in an old person with suspicion until proved unimportant by roentgenographic examination. There is usually pain, disability, swelling, and extensive ecchymosis. Crepitus, deformity, and abnormal mobility are conspicuously absent. Localized tenderness on pressure can usually be demonstrated.

Treatment.—The comminuted and impacted nature of the fracture usually renders futile any hope of obtaining anatomical restoration of the upper end of the humerus even by operative reduction. In addition,

116 117 118

FIGS. 116, 117 and 118.—Cleary aeroplane splint applied.

FIG. 119.—Ordinary aeroplane splint.

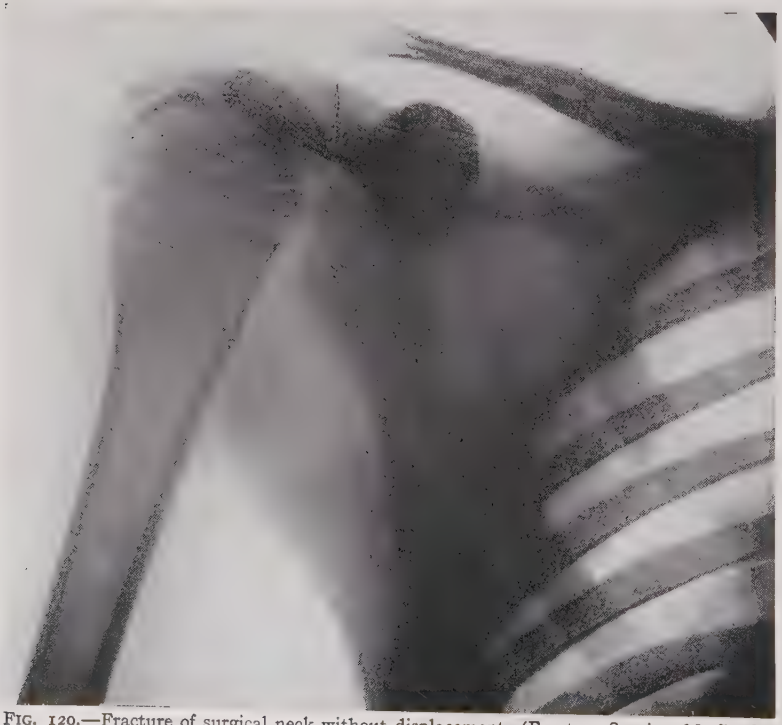


FIG. 120.—Fracture of surgical neck without displacement. (Fracture Service, M. G. H.)

the general condition of the patient is not such as to warrant undertaking any extensive surgical procedure. The lesion itself is not of a nature to produce serious functional disturbance if the ill effects of immobilization upon the muscles and joint capsule can be prevented.

For these reasons, reduction of the impaction and prolonged fixation are usually contraindicated. Instead, treatment by massage and active

FIG. 121.—Line of epiphyseal junction showing cupping of epiphysis to receive the pointed end of the diaphysis. (Piersol: Human Anatomy.)

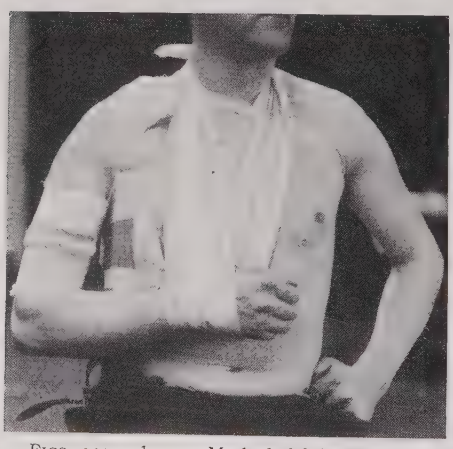
FIG. 122.—Characteristic deformity in separation of the upper epiphysis of the humerus. The prominence in front is caused by the forward displacement of the upper end of the diaphysis.

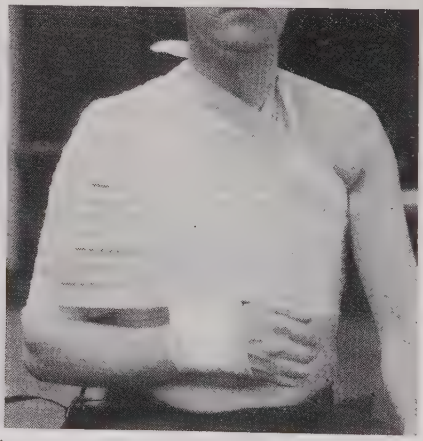
mobilization of the shoulder should be begun immediately, with the view to maintaining the function of the shoulder-joint from the beginning. Separation of the fragments in an impacted case need not be feared if the movements are performed gently.

Sufficient immobilization to give relief from pain may be obtained by the use of an axillary sweat pad, sling, and circular swathe, binding the arm to the side (see Figs. 123, 124). This dressing should be removed daily for increasing periods, and the shoulder and upper arm baked and thoroughly massaged. With the arm supported manually to remove the weight from the shoulder, the patient must be made to move it by active muscular effort. Particular attention should be given to the

movements of abduction and external rotation, which are most apt to be limited.

Convalescence is slow and tedious, but in the end surprisingly good function can usually be obtained. The body swathe may be discontinued after two to three weeks, and the patient should then be encouraged to use the hand as much as possible for light tasks. The sling is generally required for three to four weeks longer. Emphasis should be placed on active use of the arm as much as possible, and persistence in spite of a certain amount of discomfort. Failure of union is quite exceptional.





FIGS. 123 and 124.—Method of fixing the shoulder in case of separation of the upper humeral epiphysis or fracture of the anatomical neck. (123) Axillary pad of cardboard or wood, heavily padded to fill out the triangular hollow of the axilla; cravat sling to support the wrist. (124) Circular bandage over all to fix the arm to the side.

IV. FRACTURE OF THE GREATER TUBEROSITY

Etiology.— This is a fairly frequent injury and occurs most commonly in men. It is usually the result of a direct fall or blow on the shoulder, but may be produced by muscular action alone, the tuberosity being torn loose by the muscles attached to it. It frequently accompanies anterior dislocation of the shoulder.

Displacement.—The fracture usually involves a portion of the tuberosity only, and it is rare to find displacement of any considerable degree. Occasionally there is complete separation of the fragment, in which case it is drawn backward away from the head by the pull of the muscles inserted into it, chiefly the supraspinatus. If that portion of the greater tuberosity which goes to form the outer lip of the inter-tubercular groove is involved, the long tendon of the biceps may be dislocated externally.

Diagnosis.— The chief aids to the diagnosis are the presence of swelling and ecchymosis, the circumscribed area of tenderness over the tuberosity,

and the severe pain on attempted abduction and external rotation of the arm.

Treatment.— In cases of complete separation of the tuberosity, the fragment should be replaced by operation, being fixed either by a beef-bone peg or kangaroo tendon. In the more common cases with incomplete separation only, it is sufficient to immobilize the shoulder with the arm in

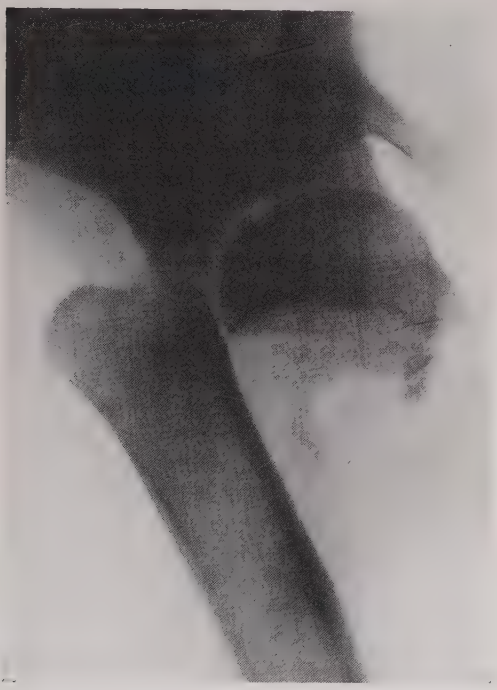


FIG. 125.—Roentgenogram of separation of the upper humeral epiphysis. Axillary view. (Fracture Service, M. G. H.)

FIG. 126.—Old fracture of the anatomical neck.

a position to relax the muscles inserted into the greater tuberosity: that is, with the arm fully abducted and externally rotated.

Fixation of the limb in this position may be obtained by a plaster of Paris jacket combined with a casing of the arm and shoulder spica. A Cleary aeroplane splint serves equally well and, if available, is less bulky and heavy than the cast. The splint must be modified to obtain external rotation of the arm by flexing the elbow and pointing the forearm directly upward. Similar fixation is required after operative reduction.

Complete fixation should be maintained for four weeks, during which time massage of the shoulder by means of an opening in the cast may be given daily. At the end of this period passive motion is begun. At the end of five weeks, a sling is substituted for the splint, and supported active

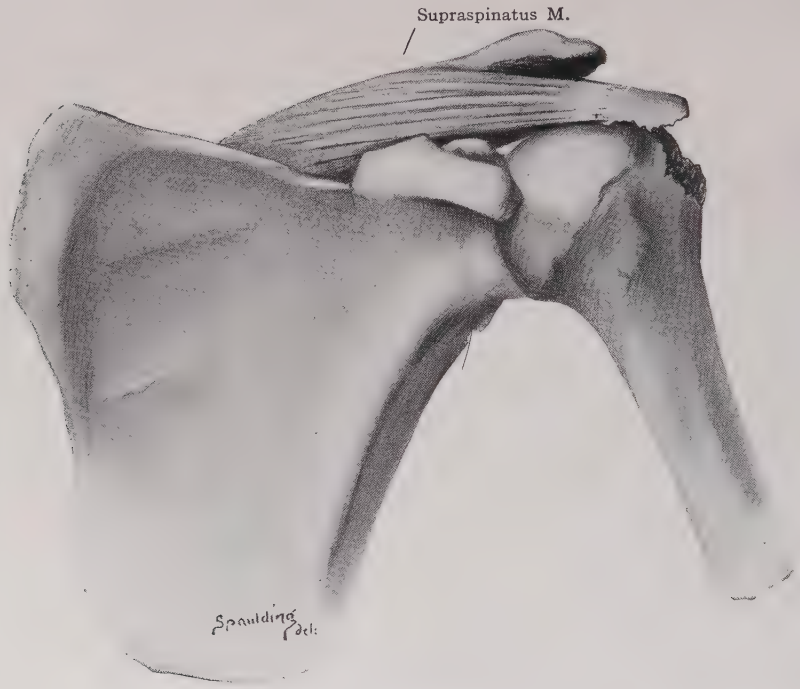


FIG. 127.—Fracture of the greater tuberosity. Diagram to show the influence of the muscles in causing displacement.

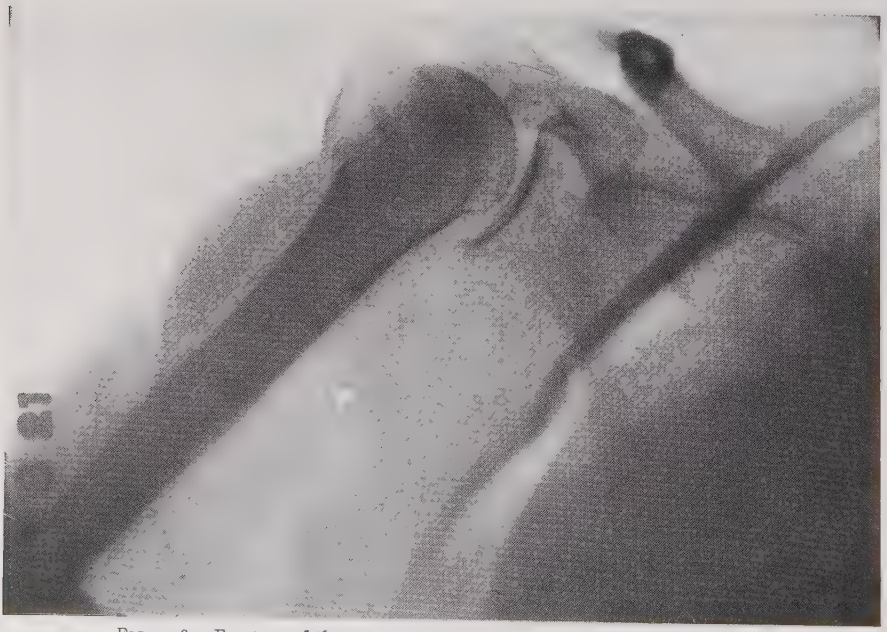
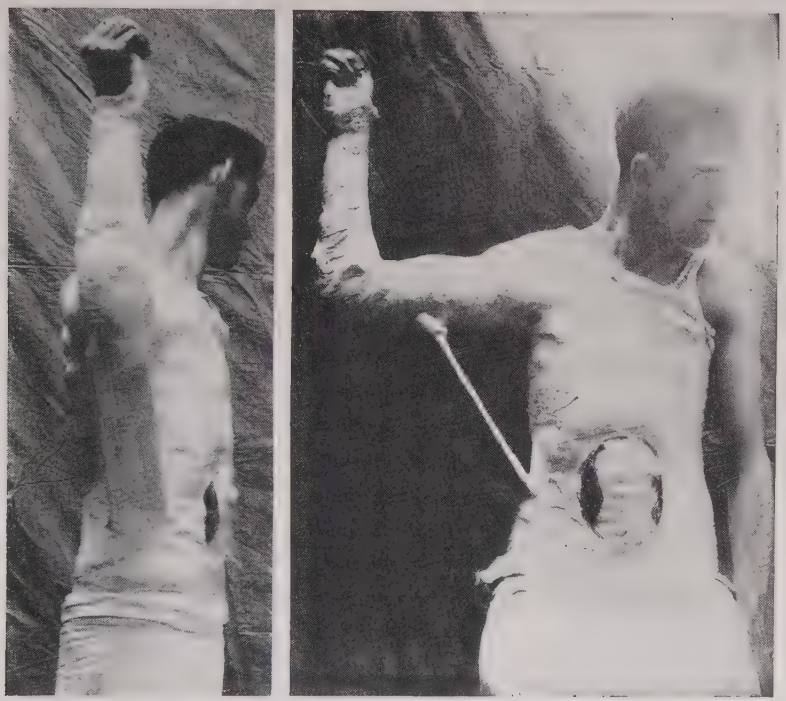


FIG. 128.—Fracture of the greater tuberosity. (Fracture Service, M. G. H.)

motions performed daily. Restricted use may be allowed at the end of six weeks, and full use at the end of eight weeks.

Prognosis.—Bony or fibrous union is usual unless complete separation has occurred. Occasionally there is formation of an excessive amount of callus, which may cause interference with full abduction or external



FIGS. 129 and 130.—Plaster jacket combined with spica of the shoulder and casing for the arm used in certain fractures of the shoulder. The arm is in full abduction and external rotation. An opening in the epigastric region reduces the weight of the cast and adds to the comfort.

rotation of the arm. As in the case of fracture of the surgical neck, the disability will be greatly lessened by treatment in the position of abduction. In most cases, a good result may be expected.

COMPOUND INJURIES IN THE REGION OF THE SHOULDER

Dislocations of the shoulder are almost never compound, and fractures in the same region but rarely so. In the latter accident, the etiological factor is almost always a gun-shot wound.

The primary wound treatment in the recent case is débridement, as in the case of all compound fractures. Complete exposure of the depths of the wound is difficult, and the Carrel-Dakin technic should be immediately applied in most cases.

For purposes of immobilization, the Thomas traction arm splint will

usually be found satisfactory, but in certain cases the position of the ring at the shoulder interferes with complete exposure of the wound. Such cases are well treated by the method of traction in abduction and overhead

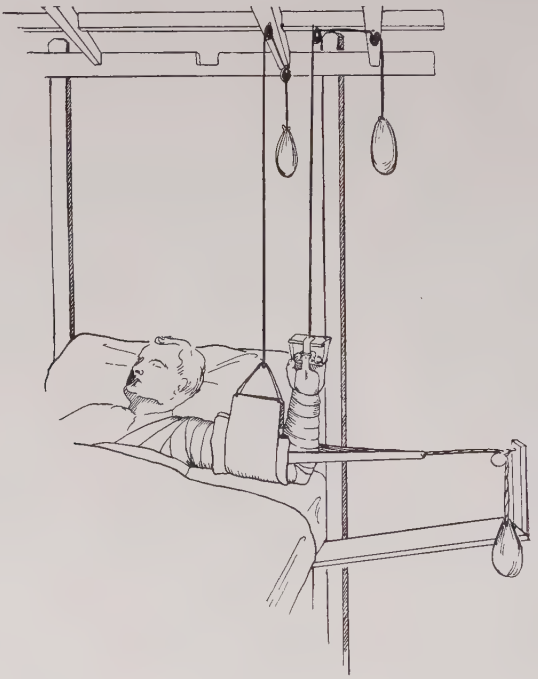


Fig. 131.—Blake's traction and suspension method of treatment for compound fractures of the shoulder.

suspension associated with the name of Blake (Fig. 131). Ample space is left free for dressings, and stiffness of the shoulder is prevented by the constant slight motion that occurs with change of position. The traction maintains alignment and adequate fixation of the fragments.

CHAPTER VI

REGION OF THE UPPER ARM

ANATOMICAL CONSIDERATIONS

Shaft of Humerus.—The shaft of the humerus begins above at the surgical neck and terminates below at the expansion forming the condyles. It is composed of dense cortical bone and in its upper half is nearly cylindrical, while below it is prismatic. It

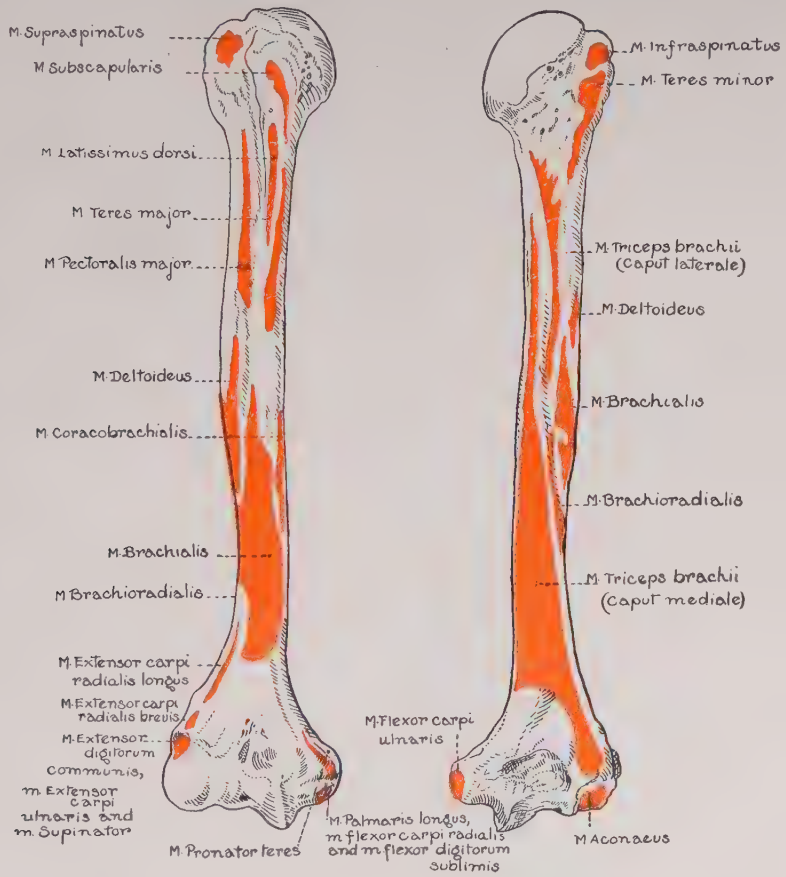


FIG. 132.—The humerus: anterior and posterior surfaces with muscle insertions indicated in red.

is doubly curved, the upper curve being with convexity forward and outward, while the lower curve is with concavity forward. The curves meet at about the middle of the shaft, and the bone itself is smallest, hardest, and least elastic at that level, and grooved by the radial nerve, facts which account in part for the frequency of fracture in this situation. The main nutrient artery enters the shaft of the humerus at about its middle and it may, therefore, be injured by fracture in this region, with resulting impairment of blood supply and tendency to delayed union.

Fascial Arrangement.—The fascial envelope of the upper arm is divided into anterior and posterior compartments by the intermuscular septa, inward prolongations of the deep fascia attached to the epicondylar ridges and shaft of the humerus as high as

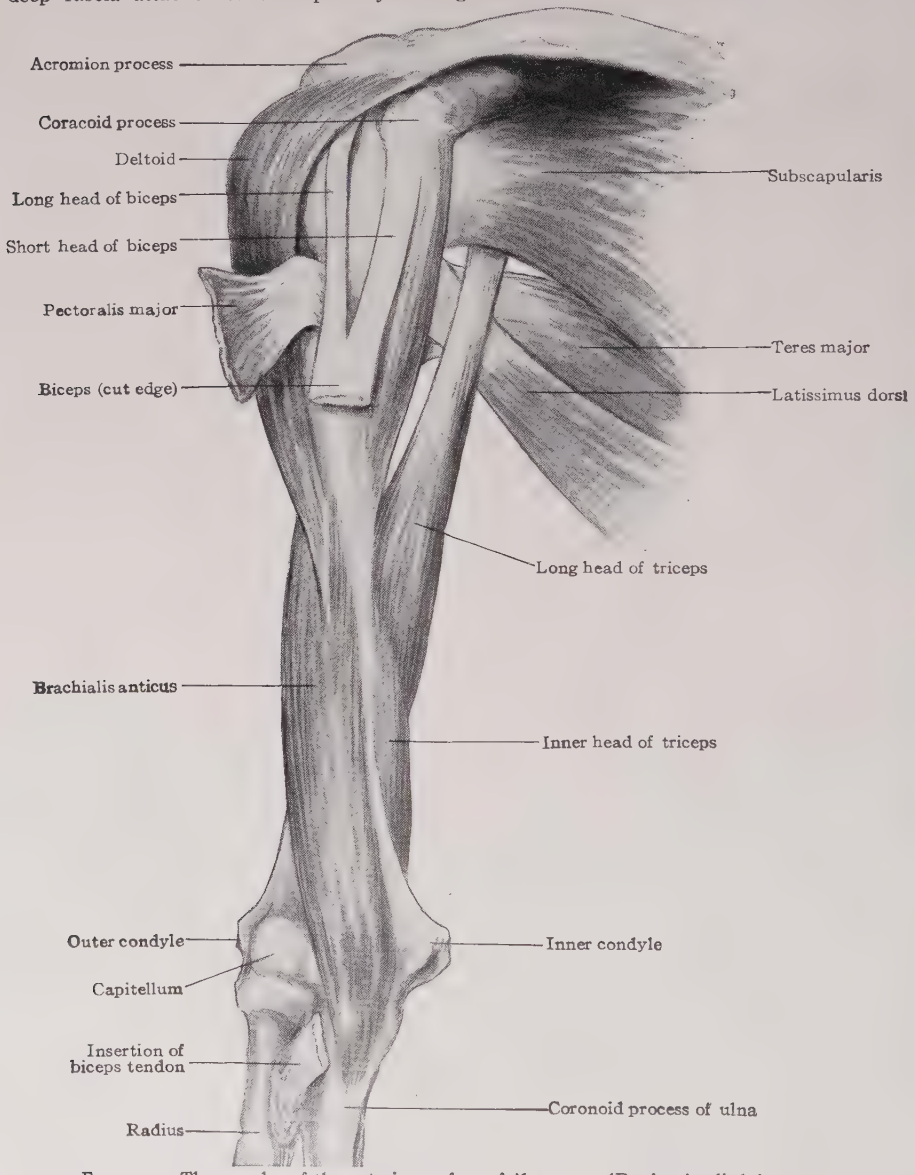


FIG. 133.—The muscles of the anterior surface of the arm. (Davis: Applied Anatomy.)

the insertion of the deltoid muscle. It is along the lines of these septa that the shaft of the bone can be most readily palpated.

Structures in the Anterior Compartment.—The anterior compartment is occupied by the coracobrachialis, biceps, and brachialis anticus muscles, the brachial vessels and the median and ulnar nerves. The vessels and nerves lie at first mesially and then

antero-mesially to the shaft of the humerus. The ulnar nerve, however, passes into the posterior compartment by piercing the intermuscular septum in the distal half of the arm.

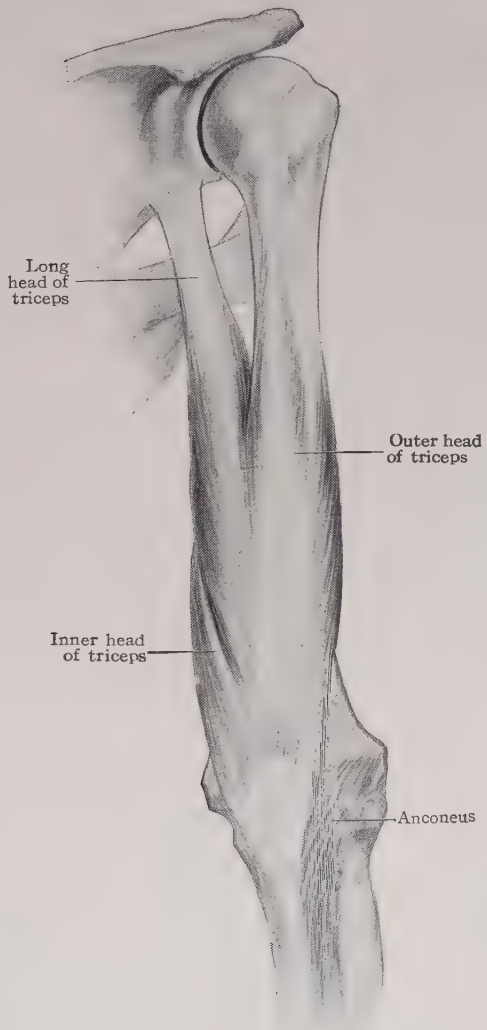


FIG. 134.—The muscles of the posterior surface of the arm. (Davis: Applied Anatomy.)

Although the neuro-vascular bundle is not in direct contact with the bone but separated from it by the interposition of muscle tissue, injury to any or all of its components may be a complication of fracture. The injury may occur as the result of the external trauma or by contusion from the sharp edge of a fragment or by the violent displacement of a portion of the bone.

The Radial Nerve.—The posterior compartment contains the triceps muscle and radial nerve. The course and relations of the latter are important from the frequency of its involvement in fracture. As it descends from its position on the tendon of the

latissimus dorsi, it lies upon the long tendon of the triceps as far as the entrance of the radial groove on the humerus. It then passes spirally around the shaft and distally

FIG. 135.—Extensively comminuted fracture of the upper end of the shaft of the humerus.

and laterally across the back of the arm on a line drawn from the termination of the axillary artery to a point on the outer aspect of the arm indicated by the junction of the middle and proximal thirds of a line joining the tip of the lateral epicondyle to the deltoid insertion.

FRACTURE OF THE SHAFT OF THE HUMERUS

Etiology.—The shaft of the humerus may be fractured at any level between the surgical neck and the upper portion of the supracondyloid ridges, the most common situation, however, being in the middle portion. Every variety of fracture is encountered. Thus, it may be oblique or spiral with considerable displacement; transverse, with but little or moderate displacement; longitudinal, fissured, or comminuted and compound. The age distribution of the fractures is not characteristic and it may occur as readily in infants as in adults or old persons.

FIG. 136.—Torsion fracture of humerus.

Causation.—The common cause of fracture is external violence, usually of the direct type as from a blow or fall. Muscular action of itself may occasion fracture as in a vigorous effort of throwing. An interesting type of violence is that produced when two men clasp hands with elbows resting on a table and each tries to force the other's hand aside. This has resulted in a spiral or "torsion" fracture of the humerus (Fig. 136). As in all fractures of long bones, the direct type of violence is most apt to produce transverse fracture, while the oblique or spiral fracture most commonly results from indirect violence. The latter is relatively uncommon.

Displacement.—The displacement in fracture of the shaft of the humerus is not characteristic except when the injury occurs above the level of the deltoid insertion. In such cases the upper fragment is apt to be adducted by the muscles inserted into the bicipital or intertubercular groove of the humerus (pectoralis major, latissimus dorsi and teres major) (see Fig. 137). The lower fragment may be slightly abducted by the deltoid, but this is not common.

When the fracture is below the level of the deltoid insertion, the displacement is determined primarily by the direction and degree of the violence. Muscular action may play a part in producing secondary displacement in combination with the influence of gravity upon the unsupported limb, as is seen in the common abduction of the upper fragment produced by the deltoid (see Fig. 138). This is, however, far from constant and in any case is not difficult to correct.

Rotational displacement, or twisting of one fragment on its long axis with relation to the other, is common and results usually from supporting the forearm across the chest in a sling. In securing this position, the

lower fragment is apt to rotate independently of the upper one. It may be recognized by the altered relation of the external epicondyle to the greater tuberosity.

There is a constant tendency to over-riding of the fragments with resulting shortening in all cases of complete fracture of the humerus.

Fig. 137.—Fracture of the shaft of the humerus above the level of the insertion of the deltoid tendon, showing the action of the pectoralis major, latissimus dorsi, and teres major in causing adduction of the upper fragment.

This is the natural result of the contraction of the muscles surrounding the humerus, but is never extreme as in the case of the femur, and the actual shortening rarely exceeds 1.25 to 2.5 cm.

Diagnosis.— The diagnosis is usually obvious. The patient is himself aware that the bone is broken, and upon gentle passive movement of the elbow, abnormal mobility and crepitus are at once evident.

Because of the possible complication of the fracture by nerve and vessel injury, it is essential to search at once for evidence of paralysis or circulatory disturbance in the hand, wrist, and forearm. "Wrist-drop" or inability to dorsiflex the wrist or extend the fingers is the sign of injury to the radial nerve. A high lesion of the median nerve causes loss of the

power to pronate the forearm and oppose the thumb to the little finger, as well as interference with many of the other movements of the fingers and hand. When the ulnar nerve is damaged there is inability to voluntarily separate the fingers. Cutaneous anæsthesia is present in the area of

FIG. 138.—Fracture below the level of the insertion of the deltoid, showing abduction of the upper fragment by muscular action.

distribution of the nerve involved. Evidence of involvement of the brachial vessels may be found in the pallor and coldness of the hand and in the obliteration of the radial pulse.

TREATMENT

General Indications.—The indications for treatment are to overcome muscle spasm and correct over-riding of the fragments by continuous

traction. The latter procedure at the same time secures alignment of the bones by virtue of the fact that the line of pull is in the axis of the limb and that the surrounding soft parts are under tension. In fracture of the shaft above the level of the deltoid insertion, on account of the adducted position of the upper fragment, the arm should be fixed close to the side of the chest. In fracture below this level, the arm may be splinted either in the position of abduction or adduction.

Reduction.—Manipulative reduction under anæsthesia is neither necessary nor desirable, as it is difficult to obtain end-to-end apposition of the

FIG. 139.—Method of measuring the length of the humerus from the angle of the acromion to the external epicondyle.

FIG. 140.—Position of wrist-drop in musculo-spiral injury.

bones, and even when secured there is immediate tendency to redisplacement. It is impossible to altogether prevent this by external fixation alone, unaccompanied by traction, as the bone is too thickly padded with soft parts to permit adequate control of the fragments.

Jones Humerus Traction Splint.—The splint which best meets all the varied indications is the Jones humerus traction splint (Fig. 141), or a hinged modification of it as shown in figure 142. It provides integral traction and counter-traction and at the same time permits free access to the injured part for purposes of examination and treatment. It is light and of not too great bulk and has the great advantage of not enclosing the chest. It secures fixation and alignment of the bones and at the same time preserves the function of the limb by permitting massage and motion of the joints above and below the fracture. Over-riding, rotational displacement, and angular deformity are well controlled.

The Modified Hinged Splint.—The Jones splint itself is open to the objection that it must be made for either the right or left arm and is not adaptable to both. The modified splint is applicable to either arm and

FIG. 141.—Jones humerus traction arm splint.

is provided with an adjustment for length so that a better fit is obtained. The forearm piece is hinged at the elbow to permit movement of this

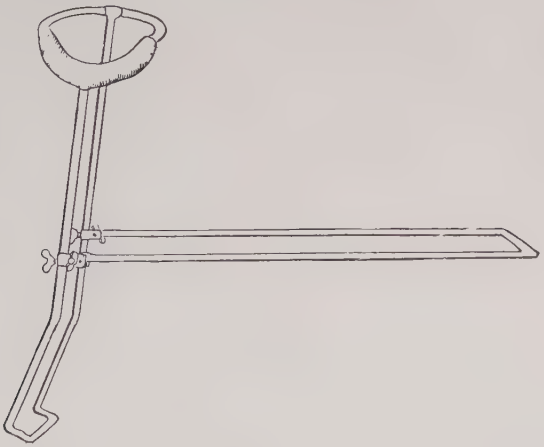


FIG. 142.—Hinged humerus traction splint (Wilson's modification). It fits either the right or left arm, is hinged at the elbow, and adjustable to different sized arms.

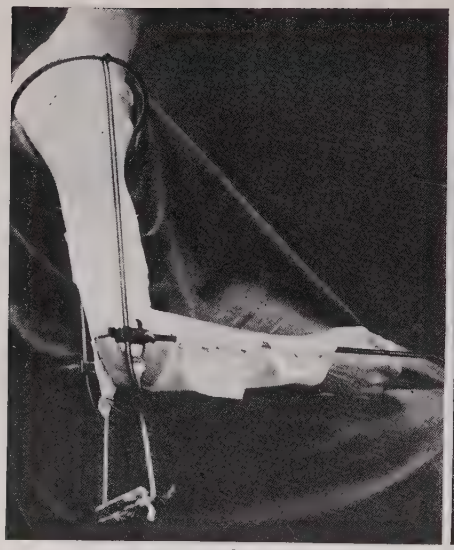
joint and may be locked by a butterfly nut when motion is not desired. The method of application is the same with both types of splint.

Application of the Splint.—The splint is applied as follows: Traction strips of adhesive plaster with cords or tapes fastened to the ends are applied to the anterior and posterior surfaces of the forearm, extending

FIGS. 143 and 144.—Application of traction strips to the upper arm, for fracture of the humerus.

FIG. 145.—Fracture of upper arm. Method of applying traction by strap passing across the upper end of the forearm. A large cotton or felt pad is placed next to the skin and above this is a small coaptation splint of wood over which the strap passes. The extension on the forearm serves merely to prevent the elbow from displacing backward in the splint.

FIGS. 146 and 147.—Application of the Jones humerus splint. The splint is applied and the traction strips secured to the lower end of the splint. The forearm is retained in position by the application of additional traction strips. The front of the splint is supported by a bandage sling. Lateral displacement of the humeral fragments may be corrected by appropriate pressure and counter-pressure with flannel slings or bandage.



148

149

150

151

FIGS. 148, 149, 150, 151.—Hinged humerus traction splint (Wilson's modification). (148) Traction is secured as in the case of the usual type of splint. The forearm support is movable and may be raised or lowered to fit the arm. It is also reversible for either right or left arm. (149) Displacement, depending upon its type, may be corrected by the use of proper slings pulling the arm to the outer or inner bars as indicated. (150) In case of posterior angulation, the humerus should be supported from the rear. By means of the lock joint, movement at the elbow may be commenced within two weeks without interfering with the alignment. (151) Shows amount of flexion possible.

from the wrist to just below the elbow. These are fixed in place by narrow strips encircling the forearm in a spiral manner and then covered by a bandage. The elbow is flexed to a right angle and the forearm supinated. Gentle traction is exerted and the forearm supported while an assistant slips the splint over the arm and draws the crutch piece upward until it rests on the side of the chest close to the axilla. The ends of the traction strips are then twisted over the side bars of the forearm piece and tied

FIG. 152.—Hinged humerus traction splint (Wilson's modification). Shows amount of extension possible.

across its end in a manner to leave freedom for the hand. The purpose of thus securing the forearm is to prevent the elbow from displacing backward in the splint. Tension of the desired degree is obtained by inserting a small stick and twisting the traction cords, and should be sufficient to hold the elbow forward in the axis of the vertical portion of the splint and in the line of pull to be exerted on the humerus.

The Elbow Traction Method.— Traction on the humerus may be obtained either by the method of pressure on the front of the elbow or by that of adhesive skin traction. In the former case a webbing strap two inches wide is passed over the forearm just below the elbow and the ends carried down and buckled to the prolongation of the splint below the elbow (Fig. 145). In order to prevent injury of the forearm by pressure of the strap and to distribute the force over as large a surface as possible, a thick pad of felt about 10 cm. square, covered by a wooden coaptation

splint of slightly smaller size should be interposed between the strap and the front of the forearm.

Adhesive Traction Method.— By the second method wide adhesive traction strips are applied to the mesial and lateral skin surfaces of the upper arm (Figs. 143,144). These strips must extend well above the level of the fracture and should be fixed by spiral strips and bandage in the same manner as in the case of the forearm. The terminal cords or tapes are then carried down and tied across the lower end of the vertical portion of the splint.

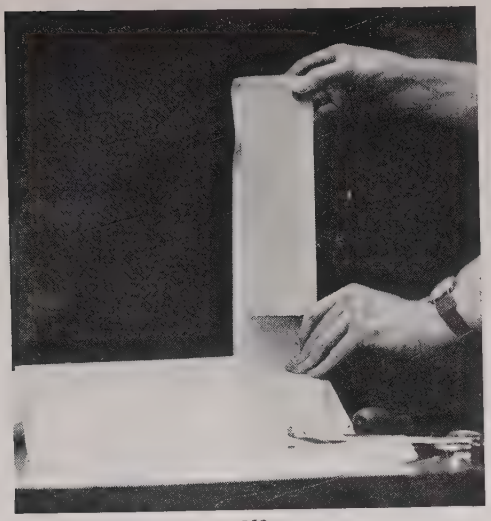
With either method the arm and forearm are supported in the splint by means of cotton slings pinned across between the parallel metal bars, thus providing a gutter in which the arm rests. For the sake of additional security the arm may be bandaged in the splint.

Choice of Traction Methods.— Both methods of securing traction are equally effective in the ordinary fracture at the middle of the shaft, but in the case of a low fracture, the elbow traction method is to be preferred. It has the advantage of leaving the upper arm free of dressing, which thus allows massage from the beginning, and it is obviously the only method applicable in case of compound fracture. The adhesive traction method is usually better in the later stage of treatment as it permits greater mobilization of the elbow.

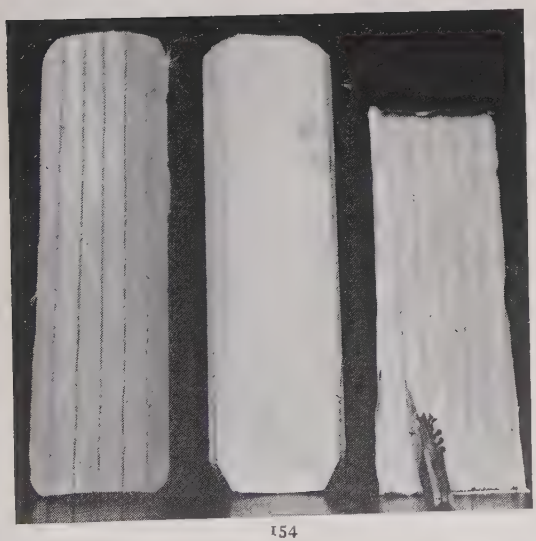
Coaptation Splints.— Wooden coaptation splints may be used in connection with the traction splint to obtain greater security of alignment. They should extend from just above the condyles as high as possible in the axilla and the posterior one should be longer than the anterior one (Figs. 153, 154, 155). They should be of sufficient width to each encircle half the arm. They are applied over abundant cotton padding and fixed with buckle straps.

Suspension of Splint.— Although this splint is essentially an ambulatory one, in most cases the comfort of the patient is promoted by keeping him in bed for the first few days. In that case the splint should be suspended to an overhead frame by means of pulleys and counterpoised by weights. If the fracture is below the deltoid insertion, the splint may be suspended with the arm in abduction, but in fracture at a higher level it should be kept adducted to the side.

When the patient is ambulatory the shoulder piece should be retained in position by means of a figure-of-eight bandage crossing over the injured shoulder and passing under the opposite axilla. The forearm piece should be supported by means of a bandage sling passing about the neck and fastened to the end of the splint.



153



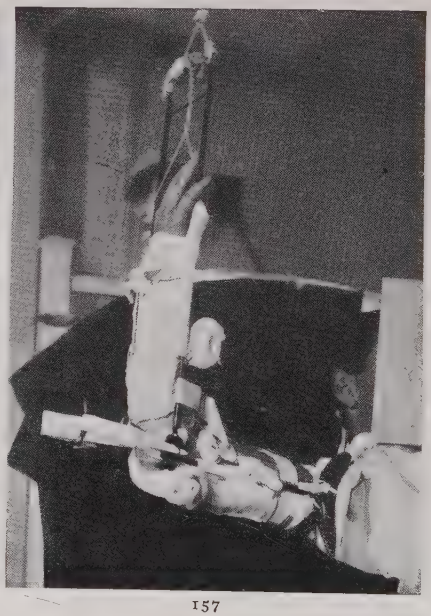
154

155

FIGS. 153, 154 and 155.—Wooden coaptation splints as used in fracture of the shaft of the humerus. (153) A piece of splint wood of proper length is covered with adhesive. (154) It is then split on its uncovered surface, forming a flexible splint. (155) The splints are applied to the anterior and posterior aspects of the arm, and are fastened with buckle straps.

Amount of Traction Required.—The amount of traction required is never great and the equivalent of five pounds is usually sufficient. When the patient is walking about it should be even less, as a certain amount of traction is obtained from the weight of the splint alone. In every case the amount of force required should be gauged by the roentgenographic appearance of the bones after several days of treatment. The common

156



157

FIGS. 156 and 157.—Recumbent treatment with the Jones humerus traction splint. Traction is being obtained by means of a webbing strap passing across the surface of the forearm and the splint is suspended in the abducted position. (157) Suspension of the splint during recumbent treatment. Note the traction strips on the forearm which serve to fix the splint in place. (Fracture Service, M. G. H.)

fault is to find that the bones are actually drawn apart too much (see Figs. 158-160). In such case the traction should be diminished.

Correction of Lateral Displacement or Angulation.—When angulation of the fragments or lateral displacement is not wholly corrected by traction combined with coaptation splints, the latter should be removed and the method of correcting the deformity by means of lateral pressure adopted (see Figs. 146 to 152). Flannel slings are passed around the arm in the region of the upper and lower fragments and the ends fastened to the side bars of the splint in a manner to exert appropriate pressure and counter-pressure in a direction to correct the deformity. However, before applying this procedure, one should first make certain that the full benefits of traction have been obtained and that all over-riding of the bones has been overcome. Displacement due to axial rotation of one fragment in relation to the other should be looked for and the normal

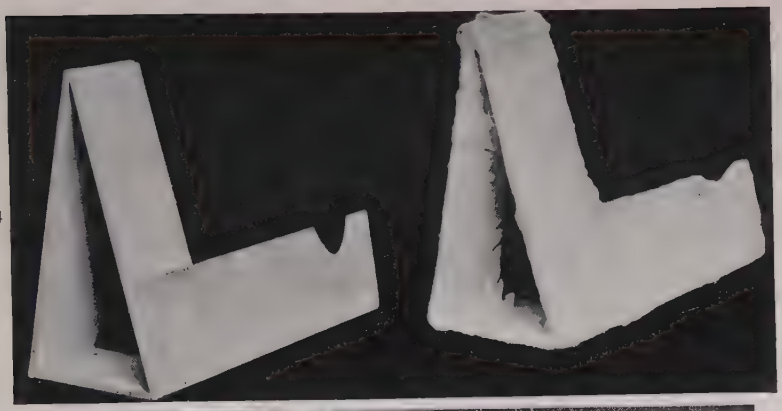
158 159 160

FIGS. 158, 159 and 160.—Roentgenogram of fracture of the humerus before and after treatment. (158) Before treatment, showing marked displacement. (159) Lateral view after application of splint. (160) Antero-posterior view. This shows quite clearly the distraction of the surfaces by the extension, which may easily become too much, unless care is used.

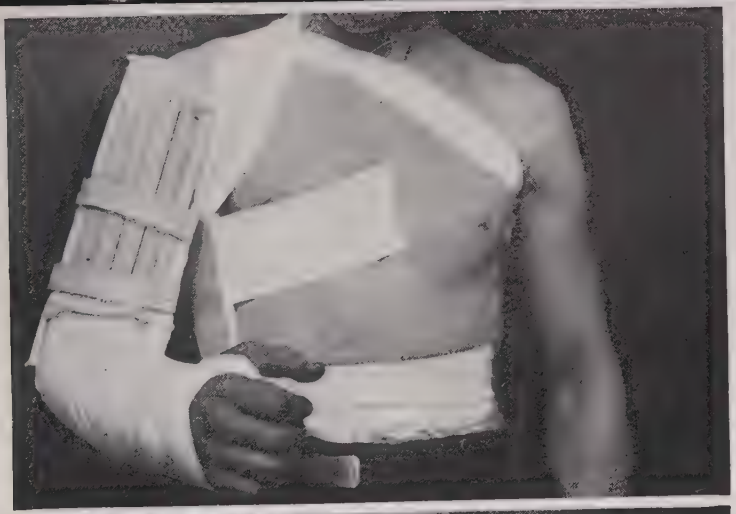
161 162 163

FIGS. 161, 162 and 163.—Oblique fracture of humerus before and after treatment. (161) Before reduction. (162 and 163) Following reduction by continuous traction with Jones humerus splint. (Fracture Service, M. G. H.)

164



165



166

FIGS. 164, 165, and 166.—Triangular axillary splint with forearm piece. (164) View of splint before and after padding. (165, 166) Splint applied, anterior and posterior views.

relation of the external epicondyle to the greater tuberosity reëstablished by rotating the lower fragment and forearm outward sufficiently.

Roentgenologic Examination.—Roentgenologic examination should be made whenever possible before beginning treatment. It is absolutely requisite after the treatment has been begun and should be repeated following each readjustment of the apparatus until satisfactory position is demonstrated. In this way the amount of traction required may be gauged and indications gained as to the measures necessary to correct other deformity. The roentgenogram should be repeated during the later stages of treatment in order to note the progress of union and the maintenance of alignment.

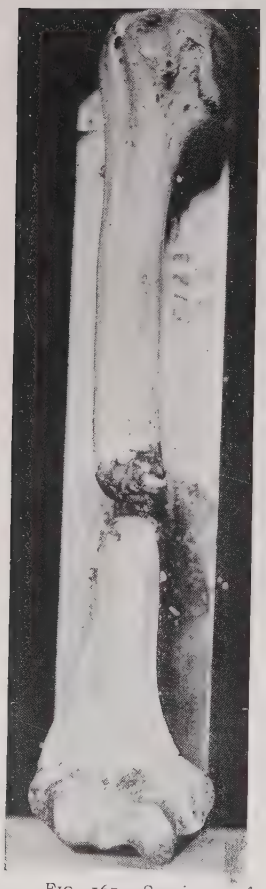


Fig. 167.—Specimen of old ununited fracture. (Warren Anatomical Museum.)

Physiotherapy.— Physiotherapeutic measures should be started immediately after injury and continued until functional recovery is complete. Massage of the upper arm should be performed daily, beginning gently and increasing its force and depth as the sensitiveness decreases. The shoulder-joint should be mobilized from the beginning, the arm and splint being moved as one piece. It is quickly possible to obtain full abduction and a considerable range of flexion and extension in this manner. Flexion and extension of the elbow in the hinged splint may be begun at the end of two weeks. Movements of the fingers and wrist should be encouraged from the beginning, the hand being left free for this purpose.

Convalescent Splint.—Union is often quite solid at the end of six weeks, but is also frequently delayed until the end of eight or ten weeks. At this stage the traction splint may be removed, but protection is necessary for several weeks longer. This may be obtained satisfactorily by the use of a triangular axillary splint with forearm splint as illustrated (Figs. 164, 165, 166). It prevents rotational deformity and is effective in maintaining alignment. Simple fractures of the shaft with little or no deformity may well be treated in this splint from the beginning.

Triangular Axillary Splint with Forearm Rest.—This splint is made from splint board and may be constructed in a few minutes. The pieces are cut to form a triangle the length of the inner surface of the upper arm and bound together with adhesive plaster. The forearm piece, of length

sufficient to extend from the palm to the elbow, is then tacked upon this base. The splint is abundantly padded with cotton, which is retained in place by bandage. It is placed in the axilla and fixed by a figure-of-eight bandage passing over the shoulder and by adhesive strapping to the chest. The projecting forearm piece is supported by a soft flannel sling passing around the neck. The arm, with the elbow flexed, rests comfortably against the splint, to which it is fixed—the upper arm by means of coaptation splints and buckle straps and the forearm by bandage (see Figs. 165, 166).

Final Treatment.—The arm is lifted free of the splint daily for massage and active motion of the joints, the limb being supported during the

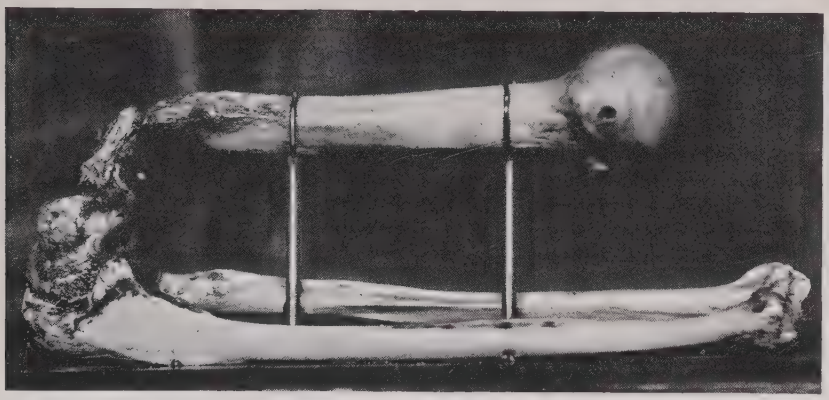


FIG. 168.—Fracture of the lower end of the humerus with loss of substance and fibrous union. (Warren Anatomical Museum.)

movements. After six to ten weeks, when firm union has been obtained, all apparatus other than a small wrist sling may be discontinued. Light use should be encouraged. Full use should be permitted gradually.

Treatment of Infants and Children.—In the case of fracture of the humerus in infants and children, simpler methods of treatment may be used. There is usually less tendency to displacement. In infants the best treatment is by an axillary triangle and coaptation splints, with narrow forearm sling and circular body bandage. In children of large size, the triangular axillary splint with forearm piece should be used. In cases with actual displacement, it will be necessary to make a traction splint of suitable size from heavy wire, not a difficult procedure.

Prognosis.—Provided that solid union is obtained without conspicuous deformity, the result in fracture of the humerus is almost always excellent. The non-weight-bearing function of the humerus is important in this respect, as the factor of static strain is not involved as it is in the case of the lower limb. From this standpoint, union with slight angulation or

deformity is of little moment, in comparison with a speedy return of the individual to work with unrestricted joint-motion and smoothly-acting

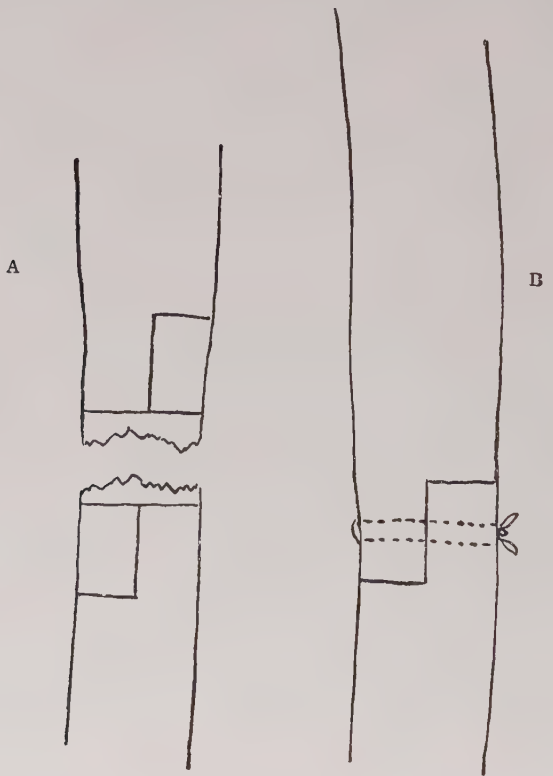


FIG. 169.—Diagram illustrating so-called "step-cut" operation. (A) Plan of bone section. (B) The fragments approximated and sutured with wire.

musculature. Good treatment must therefore place emphasis upon shortening the total period of disability to as great an extent as possible.

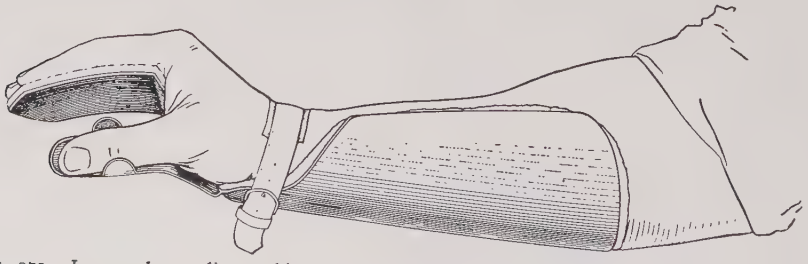


FIG. 170.—Long cock-up splint used in case of complete musculo-spiral paralysis. (Jones' Orthopædic Surgery of Injuries.)

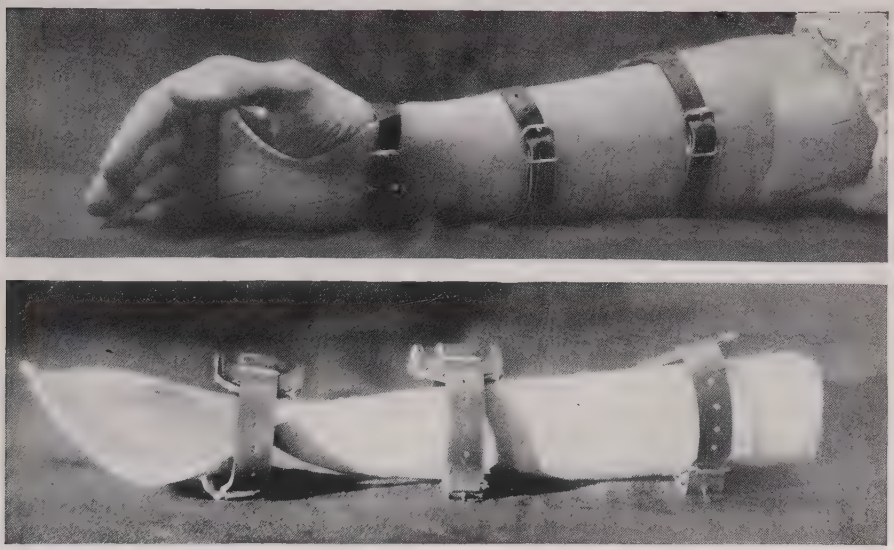
DELAYED UNION, NON-UNION

Delayed union, probably due to circulatory disturbance in the bone, is not uncommon. In cases of actual non-union, operation is necessary.

Whatever means of mechanical fixation are required, the consensus of opinion as a result of the war experience favors the use of the "step-cut" operation. Fixation must be complete and the limb should be splinted at the end of the operation by means of a well-applied plaster jacket combined with shoulder spica and arm casing with the arm in abduction.

RADIAL NERVE PARALYSIS

Of the various complications of simple fracture, injury to the radial nerve is most frequent and serious. The nerve may be injured at the time of the accident or the damage may be produced at a later stage by



FIGS. 171 and 172.—Light celluloid cock-up splint which may be used to support the fingers and wrist in case of musculo-spiral paralysis.

involvement of the nerve in callus. The treatment consists in protecting the paralyzed muscles of the wrist and hand from over-stretching by means of a long cock-up splint (see Figs. 170-172), and in maintaining their nutrition and preventing degeneration by massage and electrical treatment. If signs of returning function do not appear within two months, the nerve should be explored and the ends sutured if severed, or freed if only imprisoned in scar tissue and callus (Fig. 173).

COMPOUND FRACTURE OF THE HUMERUS

Although the humerus is well clothed with soft parts, compound fracture from direct violence is not unusual. It may be occasioned by a run-over accident or crushing injury or any severe form of trauma. In the war it was one of the most frequent of the gunshot injuries to bone. In compound fracture of the humerus there is likely to be severe damage inflicted upon the muscles and nerves, especially the radial nerve.

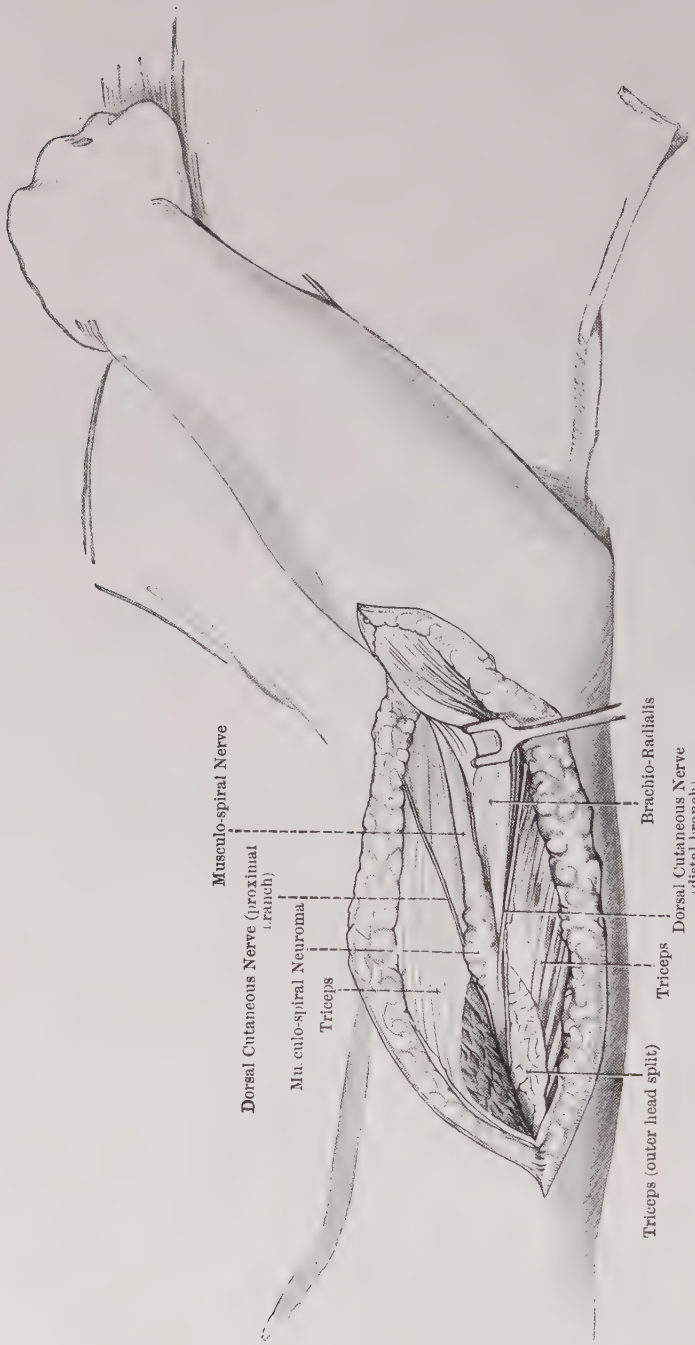


FIG. 173.—Surgical exposure of the musculo-spiral nerve, showing method of approach. (Jones' Orthopaedic Surgery of Injuries.)

The treatment of a fresh case of compound fracture should be débridement and fixation in the humeral traction splint. Traction is obtained by a webbing band passing over the proximal portion of the flexed forearm. If infection supervenes, the arm may be treated in this same splint, the latter being suspended to an overhead frame. In certain cases where sufficient

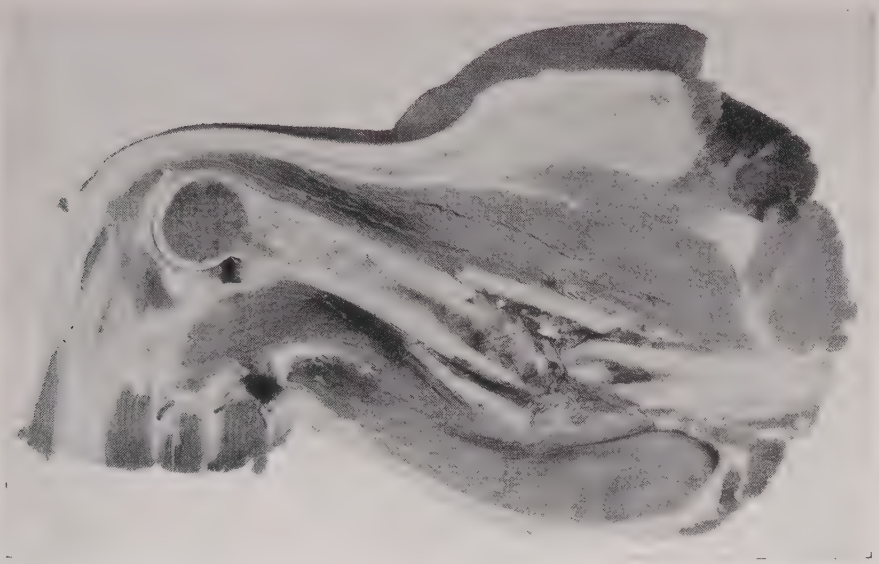


FIG. 174.—Compound fracture of the middle of humerus. Gunshot wound. (Army Medical Museum.)

access to the wound cannot be obtained in this apparatus, the Thomas arm splint may be substituted, as used in fracture of the surgical neck of the humerus (see Figs. 110, 111). Both methods enable wounds to be dressed and the Carrel-Dakin technic to be employed, without disturbing the alignment or interfering with union.

CHAPTER VII

INJURIES IN THE REGION OF THE ELBOW

I. DISLOCATIONS OF THE ELBOW

1. Posterior Dislocation of Both Radius and Ulna
2. Dislocation of the Head of the Radius

II. FRACTURES OF THE LOWER END OF THE HUMERUS

1. Supracondylar Fracture
2. Transverse Diacondylar Fracture
3. Fracture of a Single Condyle
4. Intercondyloid or " T " Fracture
5. Fracture of an Epicondyle
6. Epiphyseal Separation

III. FRACTURES OF THE HEAD AND NECK OF THE RADIUS

IV. FRACTURE OF THE CORONOID PROCESS

V. FRACTURE OF THE OLECRANON

ANATOMICAL CONSIDERATIONS

Lower End of the Humerus.—The shaft of the humerus begins to broaden in its lower third, and the supracondylar ridges, which are the thin lateral borders, flare out sharply below to form the condyles. Each ridge terminates in a small projecting knob, called the epicondyle. The one on the mesial side is much the more prominent and is grooved behind for the ulnar nerve. The articular margin is situated below the level of the epicondyles and is divided by a median ridge into two portions of unequal size. The larger and mesial one, which is continued on to the posterior surface, is the trochlea and articulates with the sigmoid cavity of the ulna. The smaller and lateral one is the capitellum which articulates with the head of the radius. Above the trochlea in front is a depression which receives the coronoid process of the ulna in flexion, and above the capitellum is a similar fossa, but smaller, to receive the head of the radius. Above the trochlea on the posterior surface is the large olecranon fossa, which receives the tip of the olecranon when the elbow is completely extended. The bone at this point is so thin that it is translucent, and fracture at this level occurs with considerable frequency.

Ossification of the Lower End of the Humerus—At birth the lower end of the humerus is cartilaginous. At the end of the second year a centre appears for the capitellum and lateral part of the trochlea. In the fifth year a centre appears for the mesial epicondyle and remains separate from the rest of the epiphysis. In the fifteenth year, centres appear for the lateral epicondyle and remainder of the trochlea. The three lateral centres fuse at fourteen years and unite with the shaft at seventeen, and the centre for the mesial epicondyle joins a year later.

Upper End of the Ulna.—The upper end of the ulna is broad and thick. Hollowed out of its anterior surface is the large sigmoid cavity, which articulates with the trochlea of the humerus. This cavity is further deepened at its distal end by the projection of the coronoid process from the anterior surface of the ulna. The cubical portion of the shaft lying proximal to the sigmoid is the olecranon. The small semilunar depression on the outer surface of the coronoid is the lesser sigmoid cavity, which

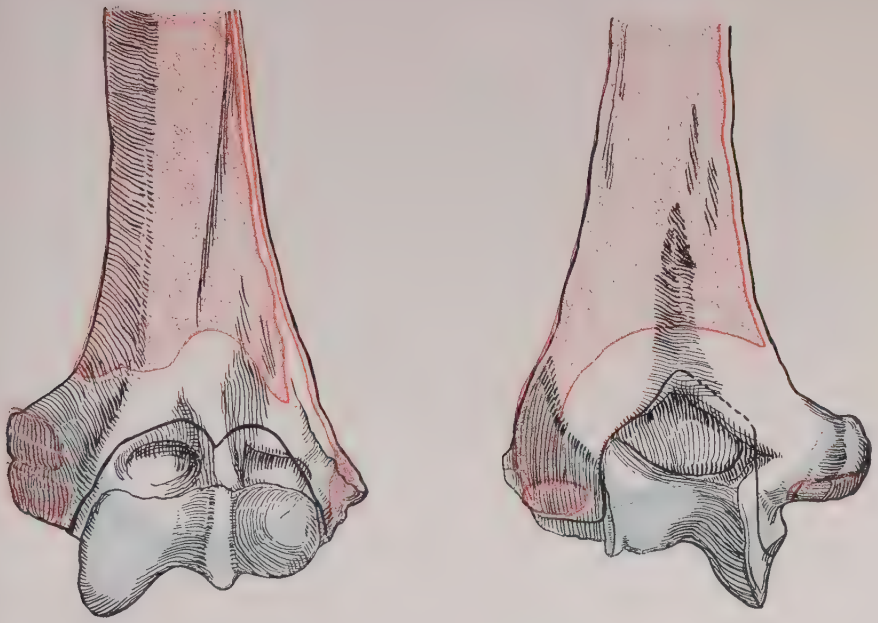


FIG. 175.—Lower end of the humerus. (Anterior and posterior views.) The muscle attachments are shown in red, the epiphyseal cartilage in blue, and the line of capsular attachment in black.

FIG. 176.—Upper end of the ulna and radius (posterior aspect). The muscle attachments are shown in red, the epiphyseal cartilage in blue, and the line of capsular attachment in black.

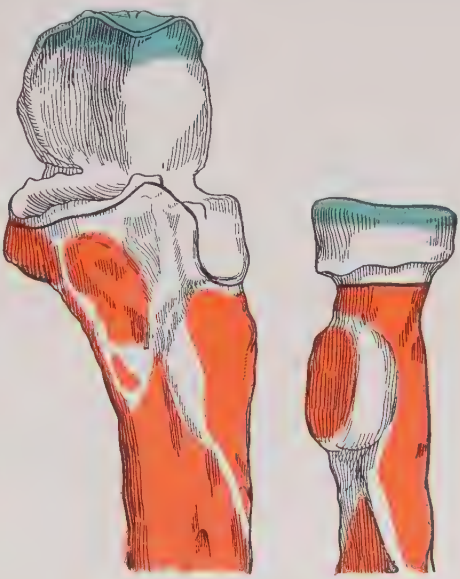


FIG. 177.—Upper end of the ulna and radius (anterior aspect). The muscle attachments are shown in red, the epiphyseal cartilage in blue, and the line of capsular attachment in black.

receives the head of the radius. The ulna is weakened by the sigmoid excavation, and fracture through the constricted portion constitutes the common fracture of the olecranon.

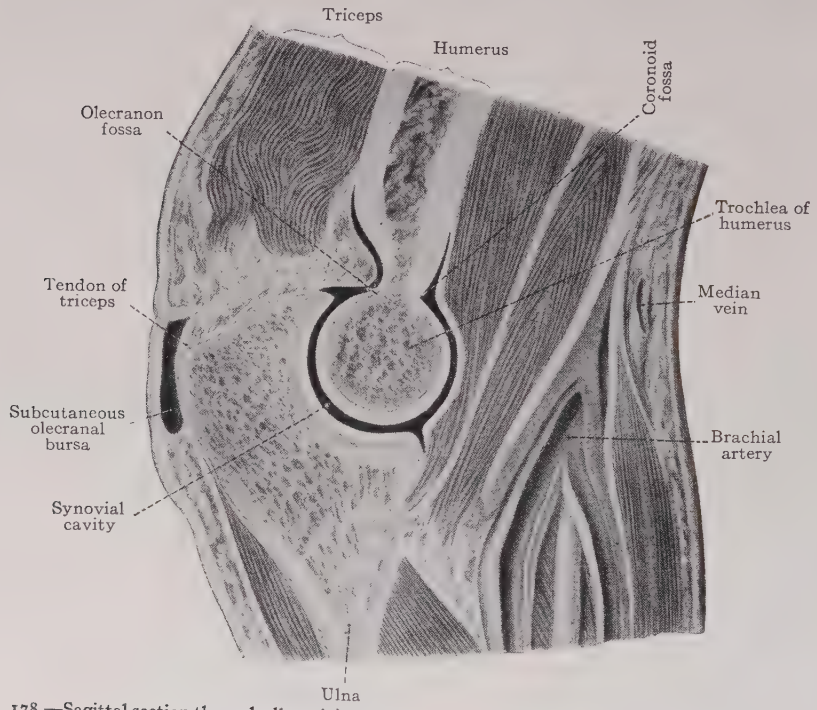


FIG. 178.—Sagittal section through elbow-joint to show the contour of the articular surfaces and the relation of the capsule and muscles. (Sabotta: Human Anatomy.)

The Upper Ulnar Epiphysis.—The upper epiphysis of the ulna is very small, takes only a small part in the formation of the sigmoid and lies almost altogether extracapsular. It appears about the eighth year and unites in the sixteenth year. It occupies a protected position, and the force that would produce a separation, more easily produces fracture of the olecranon. For these reasons separation of this epiphysis is extremely rare.

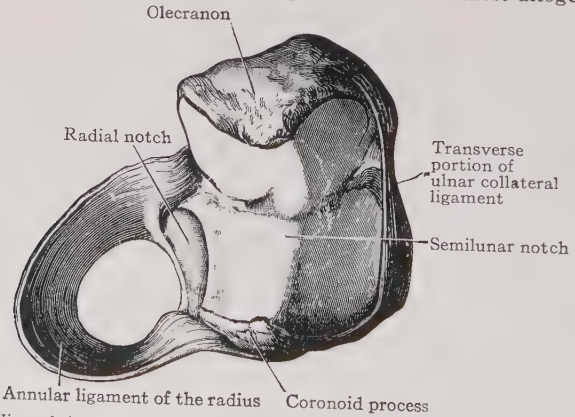
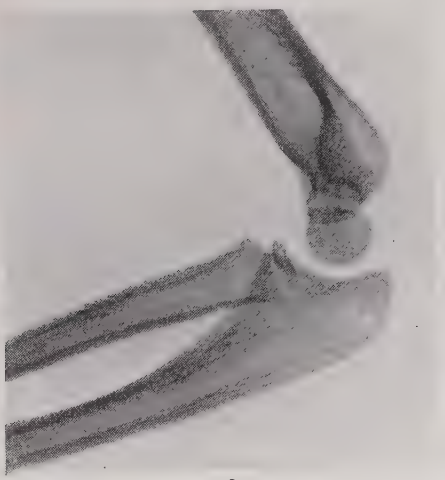


FIG. 179.—View of the upper articular surface of the ulna, showing also the orbicular ligament, which retains the head of the radius in place, and the lesser sigmoid articular facet, which articulates with it. (Cunningham: Text-book of Anatomy.)

The Upper End of the Radius.—The upper end of the shaft of the radius presents a constricted cylindrical portion 2 cm. long, the neck, which terminates in the head shaped like a round, flat disk. The head is covered with articular cartilage, and its top, which contains a rounded depression, is called the fovea and articulates with the capitel-

180

181



182

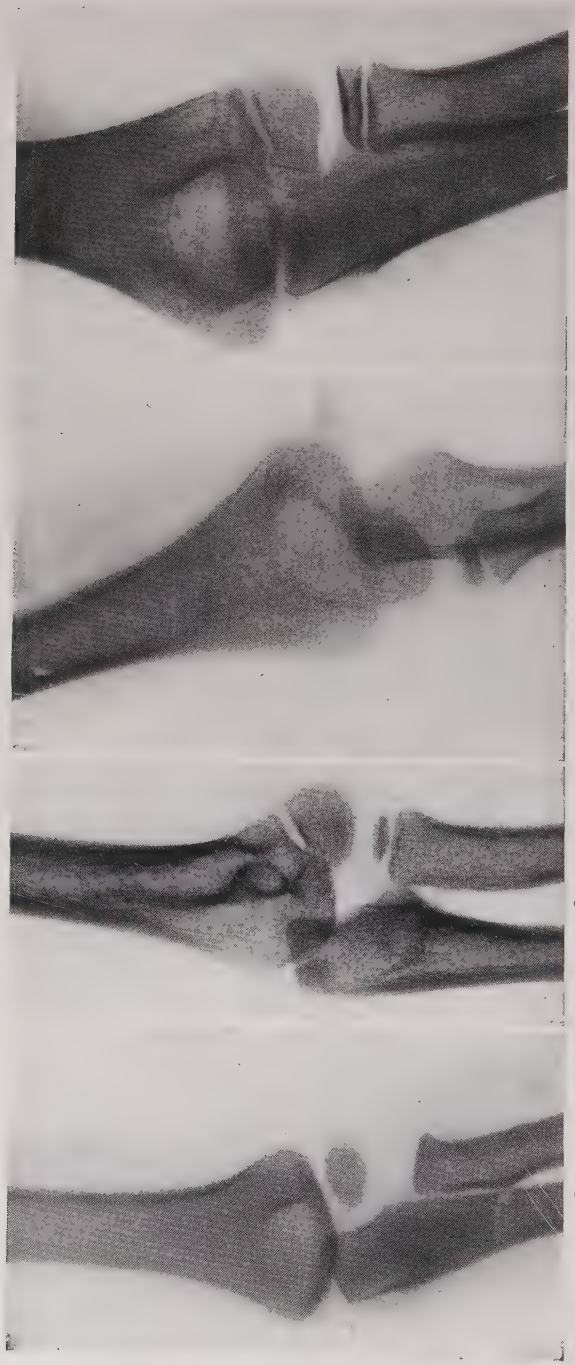
183

FIGS. 180, 181, 182 and 183.—Development of the epiphyses of the elbow. Lateral roentgenograms. (180) Age of two years. (181) Age of three years. (182) Age of seven years. (183) Age of eleven years.

lum. At the junction of the neck with the shaft is the prominent bicipital tuberosity for the attachment of the biceps tendon.

Upper Radial Epiphysis.—The upper portion of the head of the radius has a separate centre of ossification, which appears about the fifth year and unites with the shaft at the age of 15-18 years. It includes only the proximal portion of the articular surface, lies wholly intracapsular, and separation of it is almost unknown.

The Joint Capsule.—The capsule of the elbow-joint is attached in front to the articular margins of the humerus and ulna, but posteriorly is continued upward a considerable distance on the humerus in order to permit the ascent and descent of the

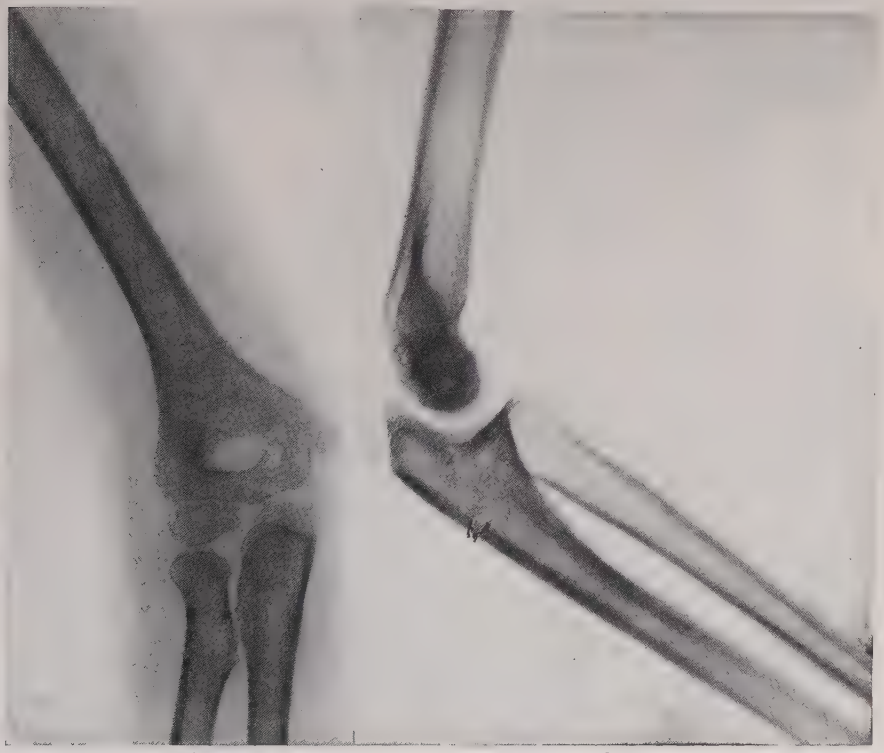


184 185 186 187

FIGS. 184, 185, 186 and 187.—Development of epiphyses of the elbow. Antero-posterior roentgenograms. (184) Age of two years. (185) Age of three years. (186) Age of seven years. (187) Age of eleven years.

olecranon, in extension and flexion. Laterally and mesially, it is attached to the base of the epicondyles. As the lateral epicondyle is small and flat, practically all fractures through its base are intra-articular. The mesial epicondyle, on the other hand, projects a considerable distance beyond its capsular attachment, so that fractures through it are commonly extra-capsular.

Orbicular Ligament.—The radius is bound to the lesser sigmoid of the ulna by a very strong circular band, the orbicular ligament, which encloses the head and permits it to rotate freely (Fig. 179). The distal margin of the ligament is unattached, and



188 189

FIGS. 188 and 189.—Antero-posterior and lateral roentgenograms of normal elbow in child of six to show the development of the epiphyses.

through the space between it and the radius, protrudes a small pouch of synovial membrane.

Lateral Ligaments.—The capsule of the elbow is reinforced by special thickenings on its mesial and lateral aspects, which are important, as they contribute materially to the strength of the joint. The external lateral ligament is attached to the lateral epicondyle and its fibres run distally and blend with the orbicular ligament, which it helps to support. The internal lateral ligament arises from the base of the mesial epicondyle and its fibres radiate, fan-like, to be attached along the margin of the sigmoid from the coronoid to the olecranon. The anterior and posterior portion of the capsule are reinforced by the brachialis anticus in front and the tendon of the triceps behind.

Structures in Front of the Elbow.—Occupying the triangular depression in front of the elbow, known as the cubital fossa, is the tendon of the biceps. From its mesial border spreads the bicipital fascia, which, in addition to forming the roof of the fossa, constitutes a second tendon of this muscle and receives its insertion, by blending with the

deep fascia of the forearm (Fig. 190). The mesial boundary of the fossa is formed by the pronator radii teres and the lateral boundary by the brachio-radialis muscle. Lying to the inner side of the biceps tendon is the brachial artery which terminates within the fossa by dividing into the radial and ulnar vessels. The median nerve lies to the inner side of the artery. The venous return is chiefly by way of the large median

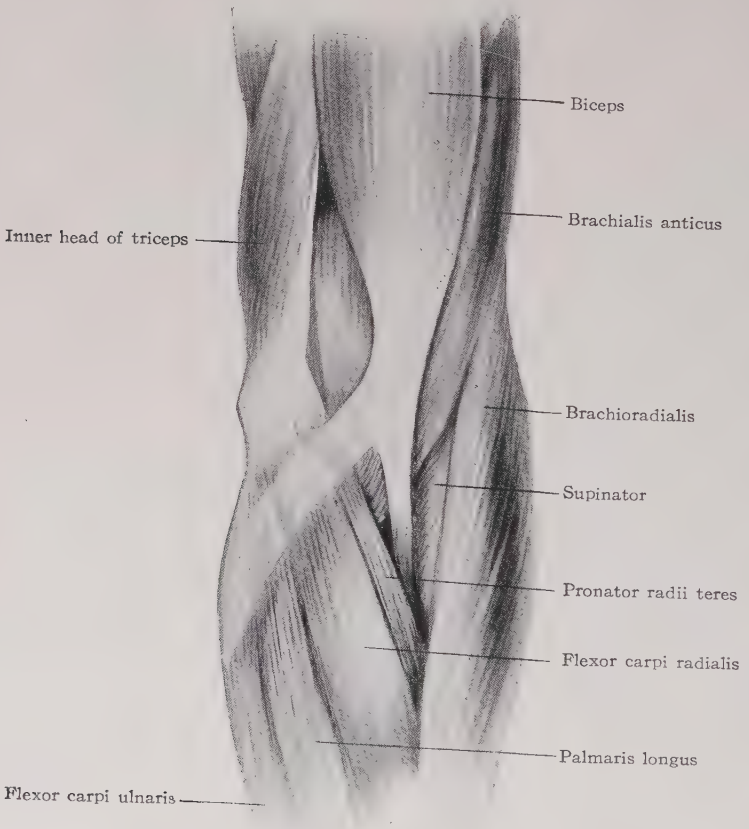


FIG. 190.—Muscles forming the antecubital fossa. (Davis: Applied Anatomy.)

basilic and median cephalic veins, lying in the superficial fascia on the front of the elbow. Care is necessary to prevent their compression by tight dressings.

Posterior Interosseous and Ulnar Nerves.—The other structures whose position it is important to note are the ulnar and posterior interosseous nerves. The latter is the terminal motor division of the radial nerve and comes off from its parent nerve in the groove between the brachialis anticus and brachio-radialis muscles, just above the elbow. It descends into the forearm by curving backward around the neck of the radius in the substance of the supinator brevis. Its point of emergence is indicated by a line drawn from the tip of the external epicondyle to the dorsal radial tubercle at a point 7.5 cm. from the epicondyle. The ulnar nerve reaches the forearm by piercing the intermuscular septum and passing backward in a groove behind the mesial epicondyle, lying between it and the olecranon. It then passes downward and forward between the two heads of the flexor carpi ulnaris.

Triceps Muscles.—The only important muscle at the back of the elbow is the triceps. Its principal attachment is to the posterior part of the proximal end of the olecranon, but in addition strong lateral expansions blend with the deep fascia on both sides of this insertion. This latter point is of importance in explaining why, in fracture of the olecranon, displacement does not occur unless these lateral expansions are torn.

The Elbow-joint as a Whole.—The elbow-joint in reality consists of three joints, although all of them intercommunicate. These are the humero-ulnar, humero-radial, and radio-ulnar portions. The humero-ulnar articulation is a pure hinge-joint, which practically permits only of the motions of flexion and extension. The radio-ulnar articulation is a swivel joint which is responsible for the rotary motions of the head of the radius. The radio-humeral articulation is of importance chiefly as a gliding surface, to allow the radius to accompany the ulna in flexion and extension, and its only other function is to prevent upward displacement of the radius through the orbicular ligament. The strength of the joint is derived from the shape of the bones and the strong ligamentous binding rather than from the surrounding muscular structures.

The elbow can usually be flexed to an angle of 30 to 40 degrees, where further motion is checked by contact of the soft parts and the impingement of the coronoid process against the humerus. Extension is allowed to 180 degrees or more and is limited by the contact of the olecranon with the bone.

Carrying Angle of the Elbow.—An interesting and important fact to note is that the forearm and arm do not form a straight line in the position of complete extension. They meet at an obtuse angle of about 165 degrees with the angle open outward (see Fig. 191). This is called the "carrying angle" because it permits the extended forearm to clear the pelvis, and thus allows heavy weights to be carried without interference with the body. In women it is more marked than in men. In flexion of the elbow, the carrying angle disappears. This is because the long axes of the ulna and humerus make equal angles with the axis of motion at the elbow. The line of the trochlea, instead of being at right angles with the shaft, slopes downward and inward. This permits the forearm to be superimposed upon the arm in flexion. In reality slight torsion of the lower end of the humerus tends to throw the forearm in flexion slightly to the mesial side of the shoulder. This is evidently a provision of nature that flexion should carry the hand to the mouth.

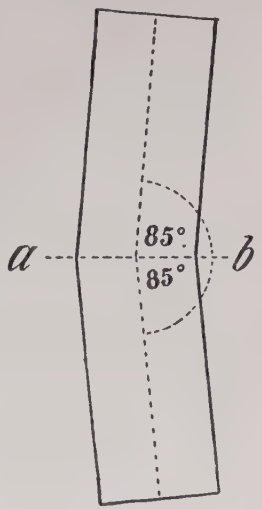


FIG. 191.—Diagrammatic representation of the carrying angle of the elbow showing the angle which the axis of the joint forms with the axes of the forearm and upper arm. (Ashhurst: Fractures of the Lower End of the Humerus.)

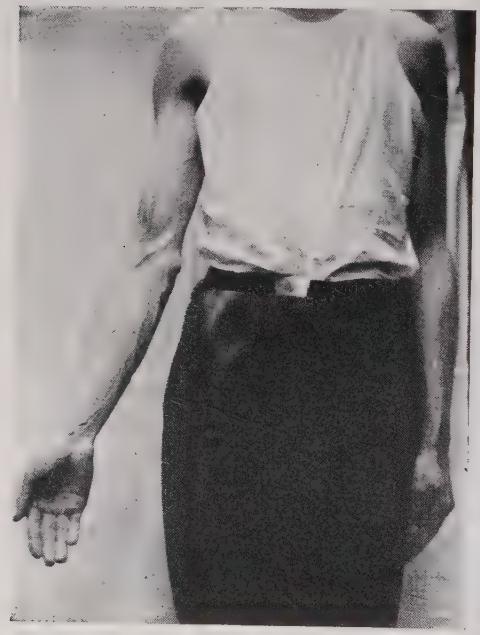
Optimum Functional Position.—In cases of complete ankylosis, the question of what constitutes the best position for function is a debatable one and will vary considerably, depending upon the occupation and whether it is the right or left hand which is affected. The right arm is generally most useful with the elbow flexed to an angle of seventy-five degrees and the left arm at an angle of about 110 degrees.

From the standpoint of early restoration of function, it is certain that a greater range of motion is more quickly regained when the elbow has been immobilized in the position of flexion than in extension. This is because the influence of gravity and the natural use of the hand in lifting and carrying objects aid in restoring the movement of extension, while return of the arm to its former flexed position is assured.

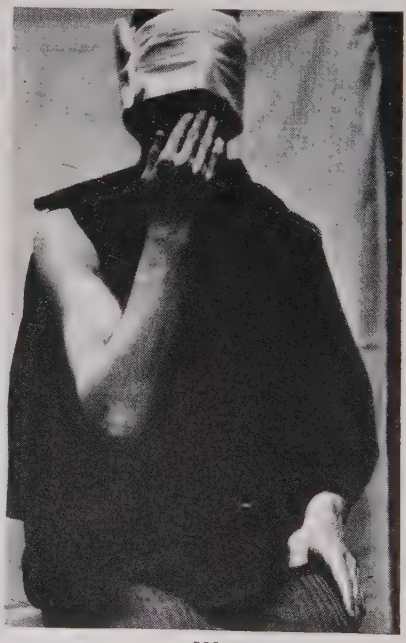
Examination of the Elbow.—It is necessary to note the relation of the bony landmarks about the elbow. The epicondyles and olecranon can be readily palpated, the inner one being much the more prominent. With the elbow extended, the two epicondyles and the tip of the olecranon lie in the same horizontal line (Figs. 195 to 197). As the joint is flexed to a right angle, the olecranon rotates distally through the arc of a circle and comes to lie at the apex of an equilateral triangle, whose base is represented

by the line connecting the epicondyles. In examining an injured elbow, these points are brought out by placing the thumb and middle finger on the two epicondyles, while the tip of the index finger covers the tip of the olecranon and follows its movements.

The head of the radius is situated on the postero-external aspect of the joint and may be palpated at the bottom of a depression or dimple when the elbow is extended. By grasping it between the thumb and index finger, while pronating and supinating the forearm with the other hand, rotation of the head may be demonstrated (Fig. 197).



192



193

FIGS. 192 and 193.—The normal carrying angle of the elbow. (192) In extension. (193) In flexion, showing how the hand is normally carried directly to the mouth.

I. DISLOCATION OF THE ELBOW

Etiology.— Dislocation of the elbow occurs next in frequency to dislocation of the shoulder. Unlike the latter, it occurs more commonly in children than in adults. This is because the bony prominences and fossæ, on which the stability of the joint to a large degree depends, are not completely developed in the childhood period.

Varieties of Dislocation.— Although a few cases have been reported of dislocation of the ulna alone, the usual displacement is of both ulna and radius together. Anatomically this is easy to understand because of their strong ligamentous connection. On the other hand, the orbicular ligament may be ruptured and the head of the radius luxated, without accompanying dislocation at the ulnar-humeral articulation.

Dislocation of both bones may occur in either the lateral or antero-posterior planes. The resistance offered to lateral displacement by the

irregularities of the joint line and the strong lateral ligaments is great, and pure dislocation of this type is not common. Displacement forward

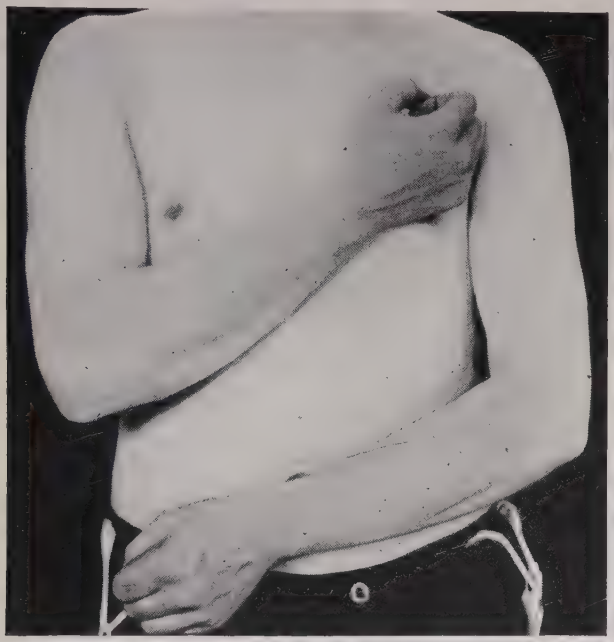


FIG. 194.—Illustrating the optimum positions of function in case of ankylosis of the right and left elbows.

is checked by the olecranon and tendon of the triceps, and rarely takes place without fracture of the olecranon. It is usually produced by a fall

195 196 197

FIGS. 195, 196 and 197.—The normal relation of the bony landmarks in the region of the elbow. (195) When the elbow is flexed, the tip of the olecranon forms the apex of a triangle, the other two angles being formed by the epicondyles. (196) When the elbow is extended, the three points lie in the same transverse line. (197) The head of the radius may be felt to rotate with movements of pronation and supination.

on the elbow. On the other hand, posterior dislocation is only resisted by the coronoid process, which in childhood is small and which can be

readily levered out of position with the elbow extended. For this reason, the posterior variety is the one most frequently encountered.

I. POSTERIOR DISLOCATION OF BOTH BONES

Mechanism.— The injury is usually produced by a fall on the outstretched hand with the elbow extended. In this position, the olecranon

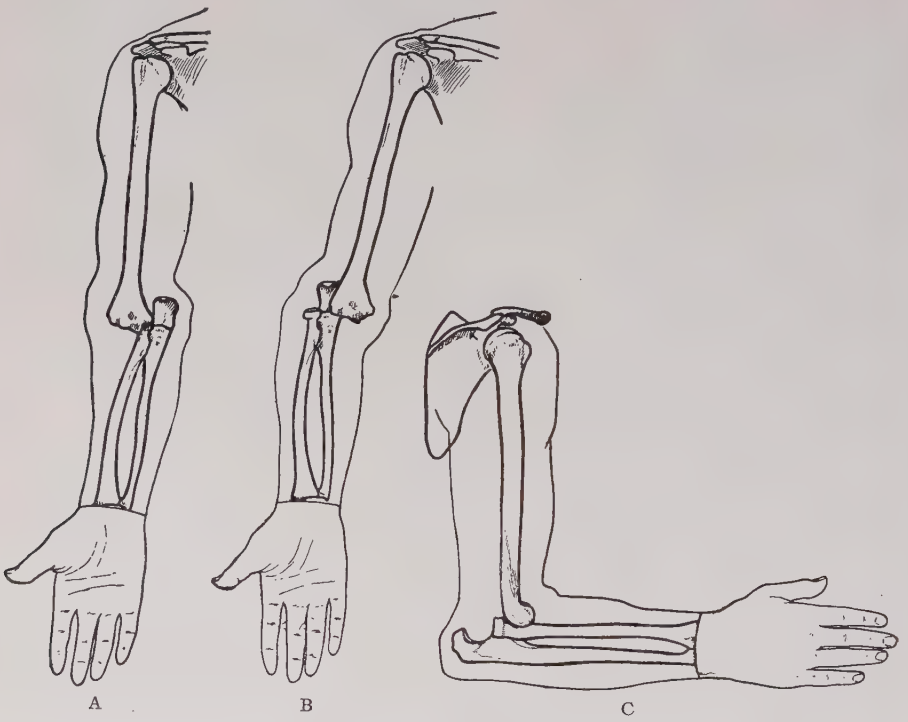


FIG. 198.—Drawings to show the various types of dislocation of the elbow. (A) Dislocation inward. (B) Dislocation outward. (C) Dislocation backward.

is fixed against the humerus, and the force is transmitted to the forearm in an upward and backward direction, producing hyperextension. The anterior capsule ligament gives way and is followed by rupture of the lateral ligaments. The coronoid process is withdrawn from in front of the trochlea by the leverage action of the olecranon, and both ulna and radius displace backward and upward, the orbicular ligament remaining intact.

Pathology.—In the dislocated position, the coronoid process lies in the olecranon fossa, and the head of the radius behind the lateral condyle. The lower end of the humerus lies in the flexure of the elbow, with the biceps tendon stretched over it. The muscle fibres of the brachialis anticus are usually torn and may be interposed between the bones.

The median nerve and brachial artery may be injured. Fracture of the coronoid may be associated with the dislocation in adults. Avulsion of one of the epicondyles or partial fracture of the head of the radius may occur. There is usually extensive stripping of periosteum and the formation of large hæmatomata.

Diagnosis.—The arm is supported across the body with the elbow in semiflexion. Motion is limited and painful. Swelling is marked. The

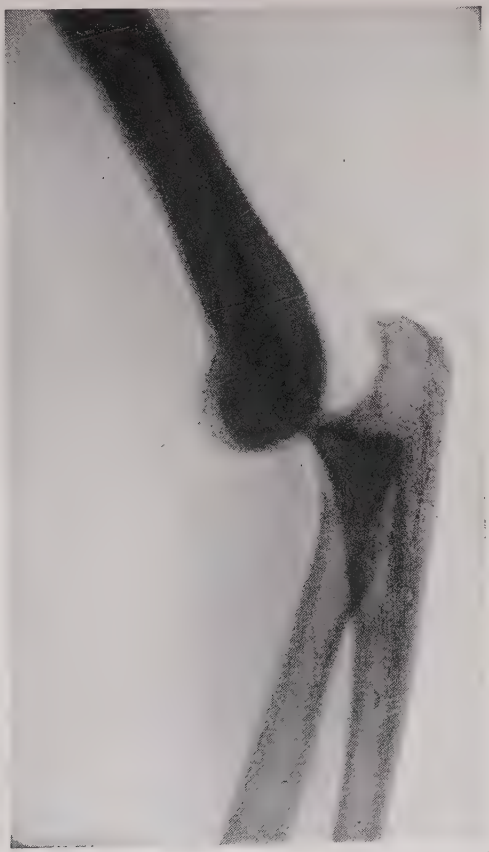


FIG. 199.—Posterior dislocation of the elbow. (Fracture Service, M. G. H.)

antero-posterior diameter of the elbow is increased. The olecranon projects posteriorly and lies in a plane considerably behind and above that of the epicondyles, while the relation of the latter prominences to each other remains unchanged. The head of the radius is missing from its normal position, and may be palpated in its new position behind the humerus if the swelling is not too great. Measurement of both arms from the lateral epicondyle to the radial styloid shows shortening on the injured side, while the distance from the epicondyle to the acromion remains

normal. Very often the bones of the forearm are displaced medially as well as posteriorly.

The only injury with which this condition may be confused is supracondylar fracture of the humerus and separation of the lower humeral epiphysis, but it should always be possible to differentiate them by measurement and by demonstrating the change in the relation of the olecranon to the epicondyles.

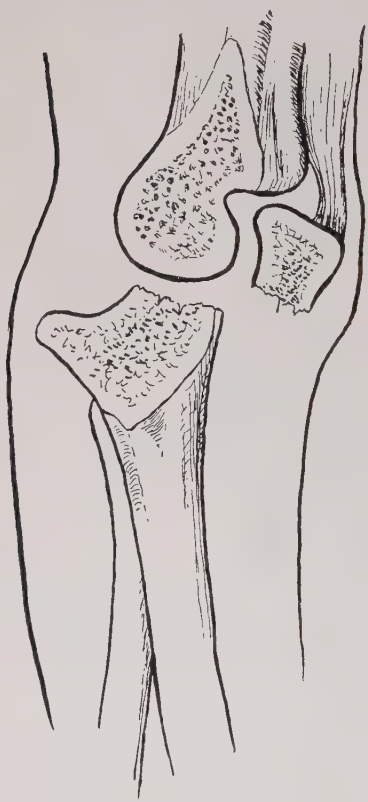


FIG. 200.—Anterior dislocation of the elbow associated with fracture of the olecranon.

A roentgenogram should be made as a routine measure, and only from its study can associated minor injuries of the bones be recognized. An incomplete form of backward dislocation sometimes occurs and may be unrecognized from the clinical examination alone.

TREATMENT

Reduction.—It is possible to secure replacement by manipulation in practically all recent cases, with the exception of those complicated by the presence of serious fracture. Such cases may require operative reduction, as also those with long-standing unreduced dislocation.

The chief obstacles to reduction are the projecting coronoid process, locked behind the lower end of the humerus by muscle spasm and the torn muscle and capsule in front. The manipulation aims to secure replacement by repeating the steps which caused dislocation, only in the reverse order. An anæsthetic is usually advisable.

With the upper arm firmly fixed by an assistant, the operator grasps the forearm and fully supinates it in order to ease the tension of the biceps. It is then completely extended to fix the olecranon against the humerus. Force is then applied to produce hyperextension, which disengages the coronoid, while at the same time strong traction is exerted downward on the forearm to secure replacement. When reduction is accomplished, the elbow is flexed acutely, in which position recurrence is least likely to occur, and fixed in this position by the application of the "hyperflexion bandage" (Figs. 234–236). In this position circulatory interference is possible if there is much swelling, and it is therefore advis-

able to keep a close watch of the radial pulse during the first few days. If the case is not seen until late after the onset of swelling it may be better to employ traction for a few days and then hyperflex the elbow.

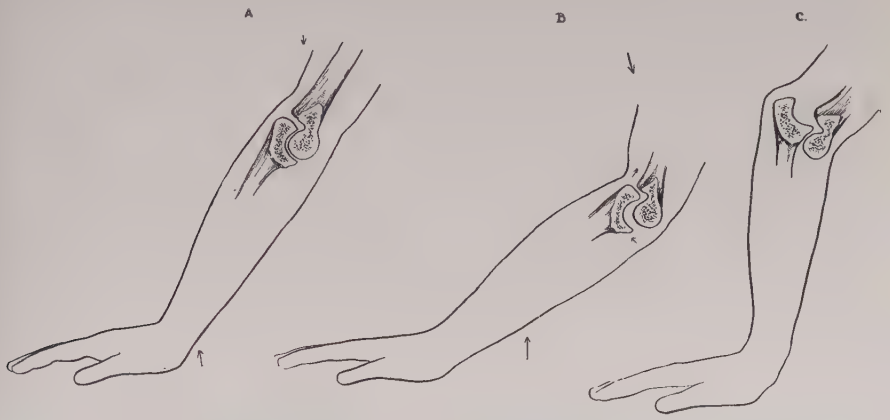


FIG. 201 (A, B, C).—The usual mechanism of posterior dislocation of the elbow. (A) In falling, the force is received on the outstretched hand. (B) This results in hyperextension of the elbow, and the coronoid process of the ulna is withdrawn from in front of the articular surface of the humerus. (C) This allows the forearm to displace backward.

After-treatment.— Massage and active motion should be begun almost immediately, restriction of complete extension alone being necessary. The movements should be performed under the supervision of the surgeon,

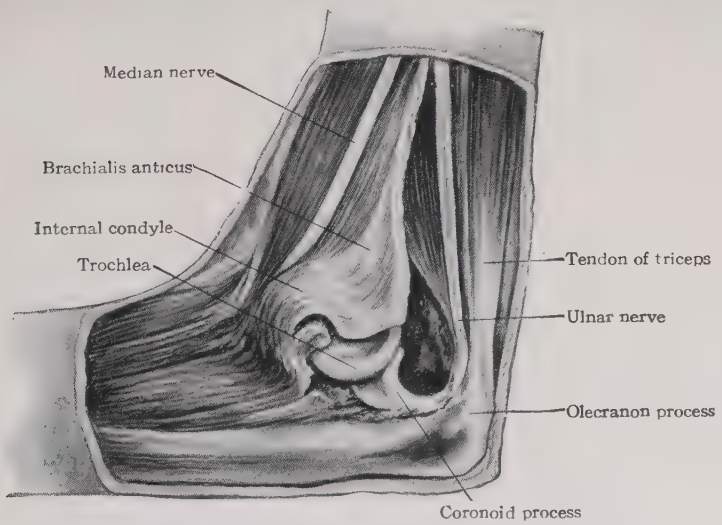


FIG. 202.—Posterior luxation of the elbow from the inner side. (Davis: Applied Anatomy.)

once or twice daily, gradually increasing the periods as the swelling subsides and absence of reaction is shown. A sling supporting the arm in right-angle flexion may be allowed after three days, with woven elastic

or flannel bandage about the elbow. The patient should be urged to flex the elbow inside the sling several times daily. At the end of two weeks, a flannel bandage with felt strips (Figs. 207, 208) should be used and the sling discontinued. Full use may be allowed at the end of three weeks. Fracture of the coronoid influences the treatment in that it predisposes to recurrence of the displacement. Full extension should therefore not be permitted before the end of three weeks.

Complications.—In uncomplicated cases, recovery usually occurs without impairment of function or tendency to recurrence.

In a certain number of cases, apparently due to the displacement of bone-forming elements at the time of injury, deposition of new bone occurs chiefly about the anterior surface of the lower end of the humerus or in the substance of the flexor muscles, and in time may cause serious interference with motion. In some of these cases, the cause may have been an unrecognized fracture of minor importance with excessive callus formation, resulting from too early and vigorous movement. In others, however, the condition more nearly approximates a true myositis ossificans, and many of these cases may be avoided by using more skill and gentleness in our manipulations and preventing unnecessary trauma. Diminution in the range of motion at the elbow following dislocation and beginning cloudiness in the muscles, as revealed by X-ray examination, are indications of the beginning of this condition, and call for complete immobilization of the joint with daily baking and massage. Operative removal of the excess bone is usually unwise before the process of new bone formation has been arrested, as otherwise it promptly reforms.

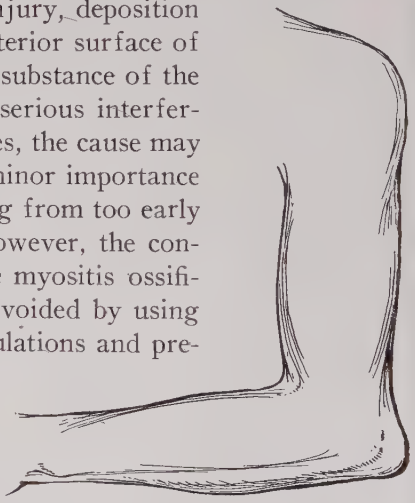
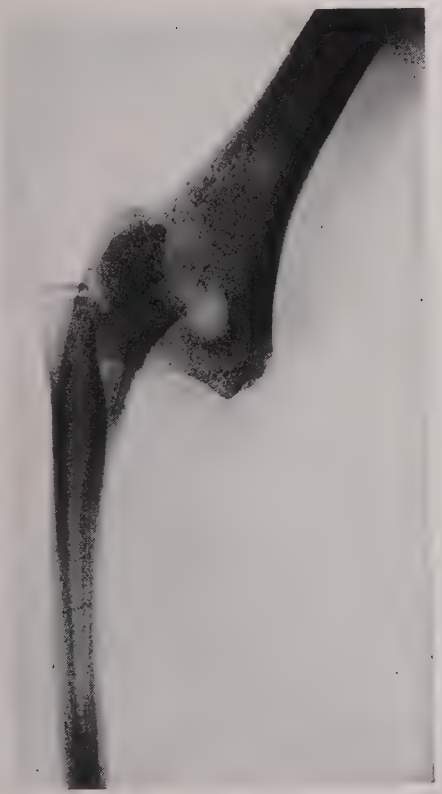


FIG. 203.—Outline drawing of the common deformity in posterior dislocation of the elbow.

Old Unreduced Dislocations.—Fortunately, there are few cases which escape reduction for a long enough time to fall within this group. After the lapse of two weeks, reduction becomes difficult, because of the binding down of the various structures in their displaced position by scar tissue. After six weeks, reduction by other than operative means should not be attempted, on account of the danger of fracture and the improbability of securing a functionating joint. In the case of children, a false joint may form eventually and permit of a certain amount of motion. Attempt at operative reduction in such cases is likely to diminish function and should be undertaken with caution.



204

FIG. 204.—Roentgenogram of posterior dislocation of the elbow. (Fracture Service, M. G. H.)

205

206

FIGS. 205 and 206.—Old unreduced fracture dislocation of the elbow, showing secondary ossification which has occurred in front of the humerus. (205) A lateral view. (206) Antero-posterior view. (Fracture Service, M. G. H.)

207 208

FIGS. 207 and 208.—Reinforced flannel bandage which is useful in the convalescent treatment of certain fractures of the elbow. (207) Strips of felt are applied on either side of the elbow. (208) These are covered with flannel bandage, forming a soft, comfortable dressing which limits movement.

2. DISLOCATION OF THE HEAD OF THE RADIUS

Luxation of the radius is of not infrequent occurrence and, unlike other dislocations of the elbow, is more common in adults than in children. It is frequently associated with fracture of the elbow and especially with fracture of the upper third of the ulna. The displacement is most commonly anterior, but may be posterior, or very rarely outward.

FIG. 209.—Compound dislocation of the elbow. The entire lower end of the humerus was protruding through the skin and badly soiled. Infection was prevented by débridement, with excision of the joint surface, and a good functional result finally obtained. (Fracture Service, M. G. H.)

ANTERIOR TYPE OF DISLOCATION

Mechanism.— In uncomplicated cases this injury is probably produced by forced pronation of the hand and hyperextension. In this position the shaft of the radius overlies the ulna and is in contact with it. A fulcrum is thus produced, and hyperextension tends to lever the head of the radius out of its socket. The orbicular ligament is nearly always ruptured, and the radial head displaces anteriorly and upwards. In some cases the cause is apparently direct violence, especially in those associated with fracture of the ulna.

210 211 212

FIGS. 210, 211 and 212.—(210 and 211) Lateral and anterior views of old unreduced posterior dislocation of the elbow, complicated by fracture of the head of the radius. (212) The same elbow following open reduction and excision of the head of the radius performed seven weeks after the injury. Good functional result.

The head of the radius can be felt in its new position, while its migration leaves a depression posteriorly which can be felt on deep palpation. Movements of supination and pronation are painful and limited.

Treatment.—Reduction is difficult on account of spasm of the biceps, which tends to cause recurrence of the displacement. Under anæsthesia, the surgeon should exert strong traction on the supinated forearm while at the same time applying direct pressure over the head of the radius

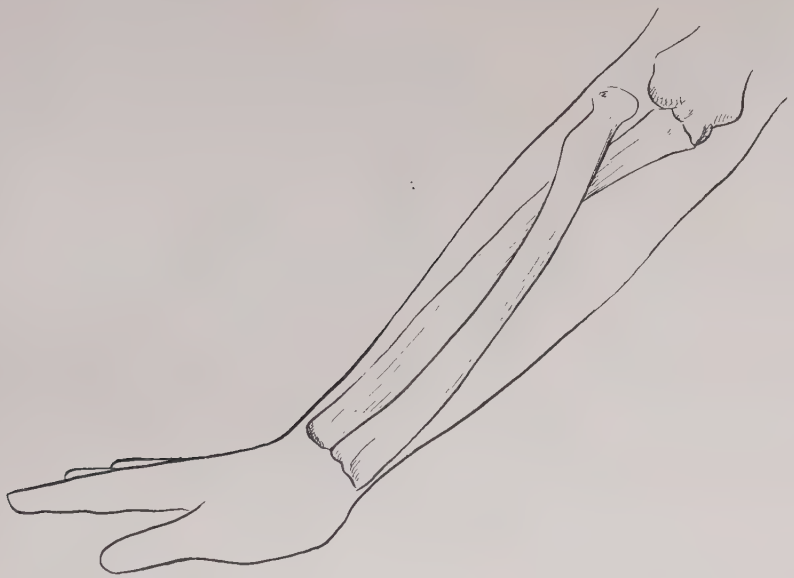


FIG. 213.—Mechanism of dislocation of head of the radius. In extreme pronation of the forearm and hyperextension of the elbow, the shaft of the radius is made to impinge on the upper end of the ulna. A fulcrum is thus provided and if the force continues, the head of the bone is levered from position.

to push it back into position. When reduction is obtained, it is best maintained by flexing the elbow acutely and fixing it with the "hyperflexion bandage" (Figs. 234, 235). The forearm should be supinated. In this position, the biceps is relaxed, and the radial head is fixed in place by contact with the humerus in front.

The position of acute flexion should be maintained for about three weeks, in order to permit healing of the orbicular ligament to take place. Motions of supination and pronation, and of flexion and extension, under the personal supervision of the surgeon, should, however, be begun within a few days. The head of the radius should be held in position by local pressure on the front of the elbow while the movements are being performed.

POSTERIOR TYPE OF DISLOCATION

Treatment.—The posterior variety of luxation is less frequently encountered, and results usually from direct violence. Reduction is most readily effected by traction with the elbow in the position of extension. Recurrence is prevented by immobilization of the arm in the extended position in a plaster casing extending from the wrist to the shoulder. This should be "bivalved" immediately and massage begun within a few days. Active supported movements should be permitted at the end of one week.

Irreducible Dislocations.—In a certain number of cases, chiefly those with complicating fractures, or in old unreduced cases, it is impossible to

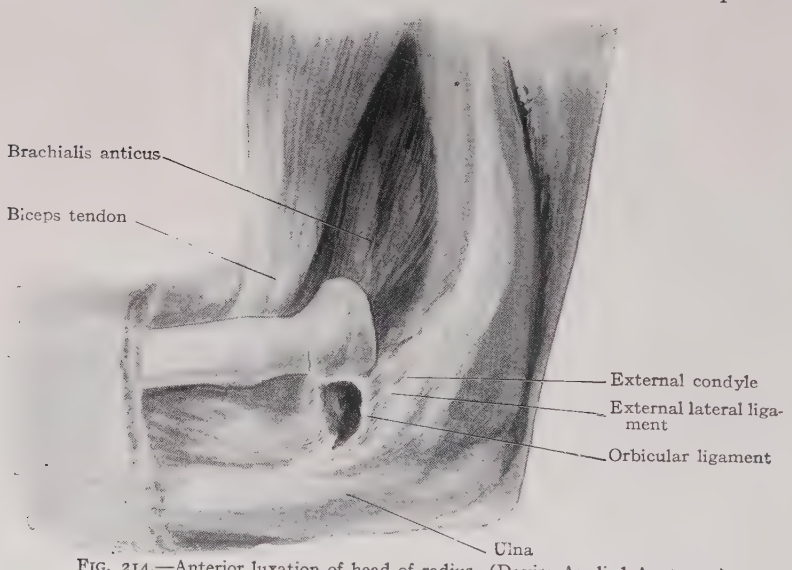


FIG. 214.—Anterior luxation of head of radius. (Davis: Applied Anatomy.)

obtain reduction by conservative measures. Such cases require operative treatment and open reduction, or excision of the head may even be necessary, especially if it exerts pressure on the radial nerve.

SUBLUXATION OF THE RADIUS OR "PULLED ELBOW"

This condition occurs only in children under the age of six and is the result of traction and torsion applied to the radius when the child is lifted by one arm or roughly dragged by the wrist.

There is immediate pain and disability of the elbow, the arm is held extended with the forearm in the mid-position, or fully pronated, and attempts at passive motion are resisted.

Reduction is easily accomplished by forcibly supinating the forearm. A slight click is felt and immediately function is restored, and the child is well. As a matter of fact, reduction usually occurs either spontaneously

or as the result of manipulation by the parents, and the surgeon is consulted only because it is feared that a serious injury has occurred. It is rare to see these cases when anything more is required than a bandage and sling.

The exact nature of the lesion has never been completely demonstrated, but the generally accepted view is that it is due to a subluxation of the

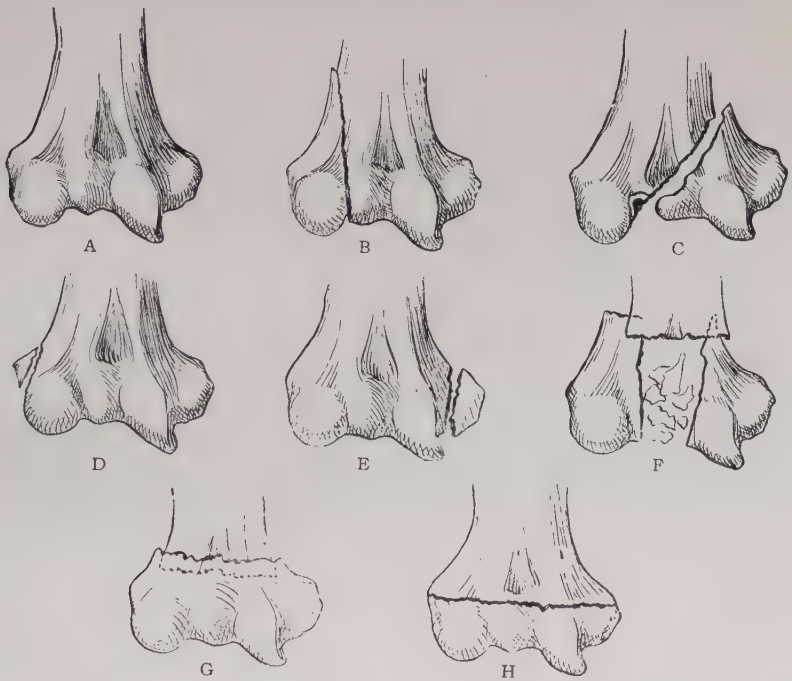


FIG. 215.—Various types of fracture of the lower end of the humerus. (A) Normal contour. (B) Fracture external condyle. (C) Fracture internal condyle. (D) Fracture external epicondyle. (E) Fracture internal epicondyle. (F) Intercondyloid or T fracture. (G) Supracondylar fracture. (H) Diacondylar fracture.

radial head from the untorn orbicular ligament, the free lower margin of which may be caught across the top of the bone.

II. FRACTURES OF THE LOWER END OF THE HUMERUS

Injuries of the lower end of the humerus are particularly frequent in children, although they may occur at any age. They comprise the following types of fracture and epiphyseal separations:

1. Supracondylar Fracture.
2. Transverse Diacondylar Fracture.
3. Fracture of a Single Condyle.
4. Intercondyloid, or "T" Fracture.
5. Fracture of an Epicondyle.
6. Separation of an Epiphysis.

1. SUPRACONDYLAR FRACTURE

Etiology and Displacement.—This injury is common in childhood and is usually produced by a fall on the outstretched hand with the elbow hyperextended. The olecranon is locked in its fossa, and leverage is thus exerted on the lower end of the humerus. The fracture line is oblique, passing downward and forward, and does not usually enter the joint. The lower fragment is almost constantly displaced backward, both by the action of the original fracturing force and the effect of the strong pull of the triceps muscle (Fig. 217). Rarely, supracondylar fracture may

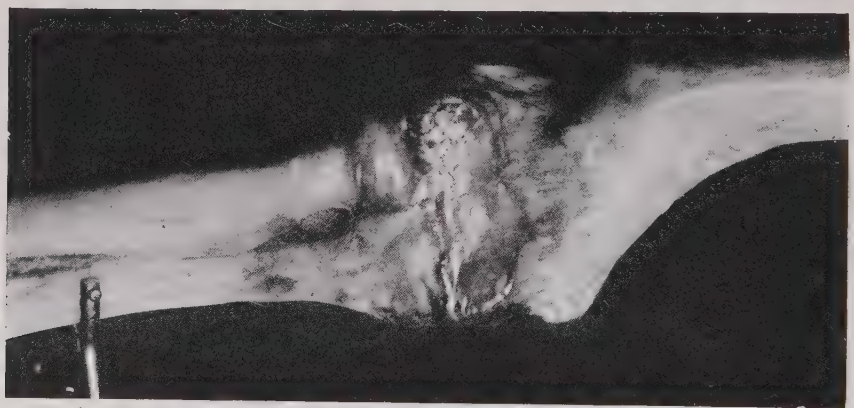


FIG. 216.—Old malunited supracondylar fracture of the humerus, anterior view. The lower fragment still occupies a posterior position, indicating the original type of deformity. (Warren Anatomical Museum.)

result from a fall on the point of the flexed elbow, in which case anterior displacement of the lower fragment is the rule.

This injury is of importance because of the frequent gross displacement of the lower fragment, with consequent alteration of the carrying angle of the arm, and also on account of its proximity to the elbow-joint, the function of which is apt to be more or less affected.

2. TRANSVERSE DIACONDYLAR FRACTURE

Special Features of the Lesion.— This injury resembles the preceding one and by many authors is not distinguished from it. The fracture line passes through the condyles instead of above them and is situated usually at the level of the olecranon fossa. The injury is always intra-articular, and this fact, which is of importance as affecting the prognosis alone, justifies singling it out for special mention. Callus formation is apt to encroach on either or both the coronoid and olecranon fossæ, with subsequent limitation of the normal range of elbow movement. The mechanism is usually a fall on the extensor surface of the forearm. The lower fragment may be displaced posteriorly, or the fracture may be impacted, with little or no displacement.

3. FRACTURE OF A SINGLE CONDYLE

Mechanism.—The lateral condyle is fractured singly much more frequently than the mesial condyle. The mechanism varies, but is usually either a fall on the outstretched arm, in which the radius is driven upward

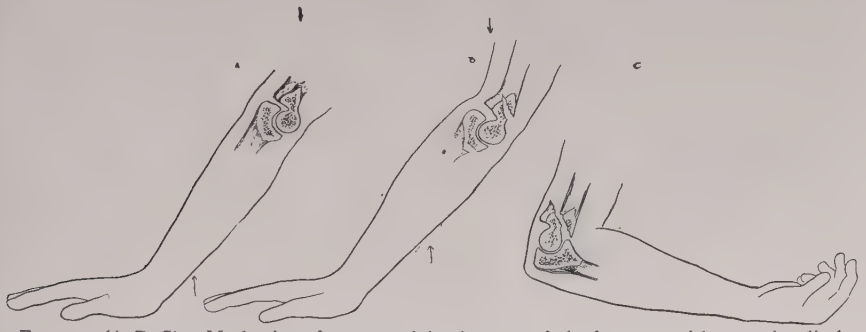


FIG. 217 (A, B, C).—Mechanism of supracondylar fracture of the humerus with posterior displacement of the lower fragment. (A) In falling, the force is received on the outstretched hand. (B) The fracture is caused by indirect violence from hyperextension. (C) The usual result is an oblique fracture with posterior displacement.

against the capitellum, or a direct blow from a fall on the outer portion of the elbow. Fracture of the mesial condyle may result from a fall on the flexed elbow, the force being transmitted to the humerus by the ulna.

Displacement.—In both types of injury, the fracture line usually begins at the trochlea and then passes obliquely upward to either the outer or

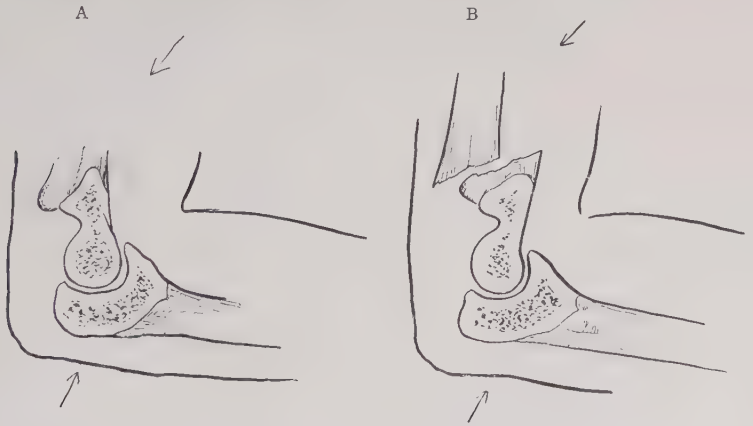


FIG. 218.—Mechanism of supracondylar fracture with anterior displacement of the lower fragment. (A) The force is received on the flexed elbow, acting in a forward direction. (B) The resulting fracture is oblique with the lower fragment displaced forward. It is unusual.

inner side, depending upon which condyle is affected. The fracture may be impacted, but usually is not. Displacement of the separated condyle, usually upward and forward, may be great or slight and depends chiefly upon the amount of the force and its direction. Displacement, if unre-

duced, produces irregularity in the articular surface and change in the joint axis, with consequent impairment of function and change in the carrying angle.

4. INTERCONDYLOID, OR "T" FRACTURE OF THE LOWER END OF HUMERUS

Special Features of the Lesion.—This is essentially an adult injury and is of infrequent occurrence in comparison with other fractures of the lower end of the humerus. It may be produced by a fall on the point

FIG. 219.—Supracondylar fracture of the humerus. Drawing showing the characteristic posterior deformity.

of the elbow, the ulna being driven upward into the trochlea, as a wedge, or it may occur secondarily in supracondyloid fracture as a result of the splintering effect of the shaft upon the condyles. Frequently it is accompanied by considerable comminution and bizarre displacement of the fragments, the external condyle being sometimes turned completely around. Such injuries threaten complete disruption of the function of the elbow-joint.

5. FRACTURE OF AN EPICONDYLE

Nature of the Injury.— Fracture of one of the epicondyles, usually the mesial one, occurs either as the result of direct violence, or of abduction or adduction strains. The fracture line in the case of the lateral epicondyle may be intra-articular, as the capsule is attached about its tip.

On the whole, however, these fractures are of comparatively little importance, as they are attended by little tendency towards displacement, on account of the muscular attachments of the bone, and the chances are small of mechanical interference with the joint function.

6. SEPARATION OF AN EPIPHYSIS

Various Types of Injury.— Epiphyseal separation at the lower end of the humerus occurs with considerable frequency, usually in children between

FIG. 220.—Fracture of the internal condyle without displacement. This case had sustained a supracondylar fracture of the humerus two years previously. (Fracture Service, M. G. H.)

the ages of 5-10 years. Only rarely is the entire cartilaginous lower end of the humerus detached; commonly, the capitellar portion alone is separated. At this age the epiphysis for the mesial epicondyle is separate from the main epiphysis, and it may be affected independently. The mechanism varies, but the most frequent cause is a direct fall on the elbow. The displacement depends upon the direction in which the force acts, but is usually posterior. In separation of the capitellar portion alone, the epiphysis, in addition to being displaced backward, may be tipped upside down as well.

Special Dangers.— Epiphyseal separation is important, partly because of its possible effect in producing disturbance of growth and asymmetrical development of the elbow, if incompletely replaced, but chiefly because of the ease with which the injury may be overlooked (Figs. 224, 225), due to the inability of the roentgenogram to reveal cartilaginous damage. An exact knowledge of the ossification of the lower end of the humerus and

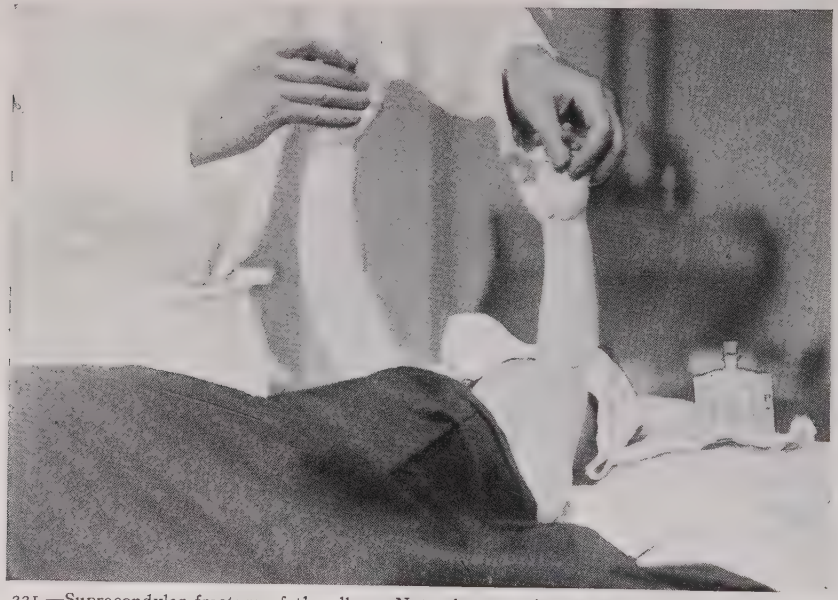


FIG. 221.—Supracondylar fracture of the elbow. Note the extensive swelling and angular deformity of the right elbow. (Fracture Service, M. G. H.)

the normal position of the various bony centres is required for the correct interpretation of the roentgenogram (Figs. 180-189).

DIAGNOSIS OF FRACTURES OF THE LOWER END OF THE HUMERUS

Although the recognition of the exact nature of an injury to the lower end of the humerus is difficult and in the last analysis will depend to a considerable extent upon the radiographic appearance, nevertheless, a fairly accurate diagnosis can be made in most cases from the history and clinical examination alone. Careful palpation is required and observation of change in the normal relationship of the bony landmarks (p. 161).

Supracondylar Fracture.—The deformity in the usual supracondylar fracture is quite characteristic and can be confused with nothing but posterior dislocation of the elbow. There is a typical backward displacement of the elbow with relation to the humerus that is seen only in these two conditions. In the case of fracture, the deformity is above the condyles,

whereas, in the case of dislocation it is the olecranon alone whose position is changed.

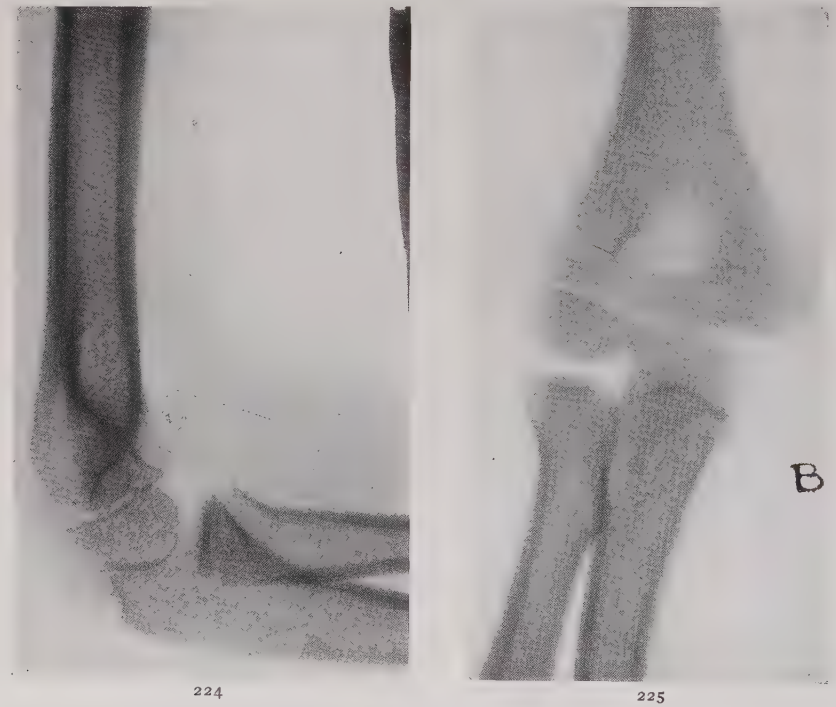
Fracture of the Condyles or Epicondyles.—Fracture of a single condyle practically always changes the joint axis in such a way as to alter the

FIG. 222.—Intercondyloid or "T" fracture of humerus.

FIG. 223.—Separation of epiphysis of internal condyle. (Fracture Service, M. G. H.)

axes of the arm and forearm. The position of the epicondyle on the affected side is altered in relation to its fellow and to the tip of the olecranon. This is also true in fracture of an epicondyle, but in the latter case it is often possible to move the bony prominence and recognize by palpation the limited extent of the injury. Intercondyloid fracture is recognizable chiefly by the "mushy" feel of the lower end of the humerus, suggesting comminution.

Epiphyseal Separation.—In epiphyseal separation, it may be possible to palpate the displaced portion of the cartilage as a rounded prominence lying to the outer side of the olecranon, on the posterior surface of the elbow. This is, however, quickly masked by swelling. The diagnosis chiefly depends upon clinical findings suggestive of severe injury, such as considerable swelling, marked tenderness, and limitation of motion,



224 225

FIGS. 224 and 225.—Partial displacement of capitellar epiphysis. (224) Lateral view, showing a slight posterior displacement. (225) Antero-posterior view. No deformity shown. (Compare with Fig. 183.)

contrasted with roentgenologic evidence of but little damage. It is important to remember in this connection that the bony centre for the capitellar epiphysis lies in a forward position, so that the line of the anterior surface of the shaft of the humerus, if projected downward, normally bisects it. If this relation is not remembered, it is easy to overlook slight posterior displacement.

GENERAL PRINCIPLES OF TREATMENT

None of the common types of fracture have so frequently resulted in disability as those involving the lower end of the humerus. This, in spite of the fact that they occur most frequently in children, a group which ordinarily is expected to yield more favorable results than any other. The explanation is found in the complex irregularity of the joint sur-

faces, the function of which may be seriously affected by comparatively slight bony displacement or callus encroachment, and the difficulty of securing alignment or maintaining reduction by the methods ordinarily used in fractures of the long bones.

As originally pointed out by Smith,[1] and since popularized by Thomas and Jones,[2] the treatment must be based on anatomic and physiologic

FIG. 226.—Fracture of the external condyle of the humerus. (Edinburgh Royal Infirmary.)

principles. The structures about the elbow must be utilized as aids in securing alignment rather than permitting them to act as deforming agents. Joint function must be preserved by early movement and in the position whence the greatest usefulness will result, if full recovery is not obtained.

[1] H. L. Smith, *Boston Med. and Surg. Journ.*, July 4, 1895.
[2] R. Jones, *Clinical Journal*, October 26, 1904.

The plan of treatment comprises three separate steps:

First: Reduction of deformity.
Second: Immobilization, with the elbow in the position of acute flexion.
Third: Early inauguration of active partial movements of the elbow.

Reduction.—Every effort should be made to obtain as exact replacement of the fragments as possible. For this purpose manipulation under

FIG. 227.—Fracture of the external condyle with separation of the capitellum. (Edinburgh Royal Infirmary.)

full ether anæsthesia is necessary when displacement exists and is advisable even when this is absent, in order to overcome muscle spasm and to obtain the position of complete flexion of the elbow. The various manipulative procedures vary with the different types of fracture and are given elsewhere under the heading of the specific injury.

Tests for Reduction.—It is important, however, to draw attention here to three points of great value in determining, at the time of reduction, whether complete replacement has or has not been obtained. The injured

arm should be compared with the uninjured side, particularly with reference to the carrying angle when the elbow is extended and the absence of limitation of motion when the elbow is completely flexed. In the latter position, the radial pulse should be palpated to show if there is compression of the brachial artery. Dissimilarity in the carrying angle, blocking of complete flexion or, in a recently injured case, shutting off

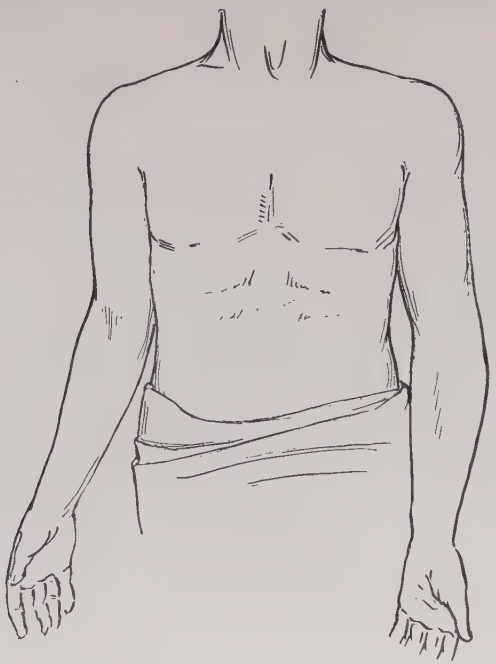


FIG. 228.—Drawing to illustrate how the carrying angle may be altered following fracture of the elbow.

of the radial pulse, are sure signs of continued displacement even when present singly, and are indications to repeat the manipulation.

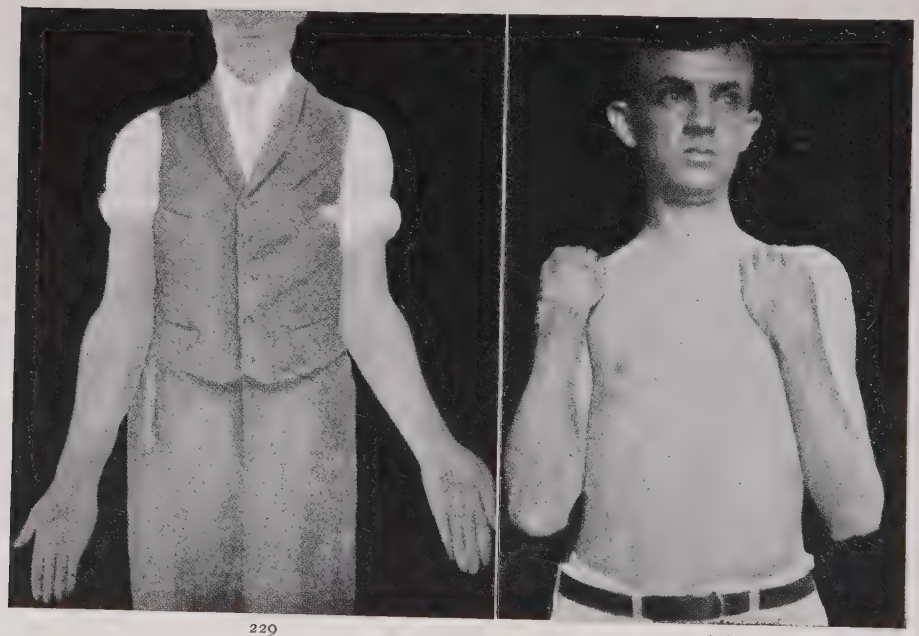
Position of Acute Flexion.— Following the manipulation the elbow should be flexed completely and the arm fixed in this position. The position desired is one with the forearm doubled against the upper arm as closely as it may be forced. The hand should be against the shoulder and not across the chest. Ashhurst[3] calls it hyperflexion. The reasons for immobilizing the elbow in this position are three:

1. It splints the bones and holds them in their reduced position better than any other method. The lower end of the humerus is drawn forward and splinted between the bones of the forearm in front, and the broad tendon of the triceps stretched taut across the elbow behind. The muscles of the anterior portions of the arm and forearm are relaxed, and the

[3] A. P. C. Ashhurst, *Fractures of the Elbow,* Lea and Febiger, Philadelphia, 1910.

lower insertion of the triceps is pulled forward in front of the axis of the humerus so that it exerts a corrective instead of deforming influence. The position is also one that tends to correct rotational displacement of the lower fragment, and by preserving the normal axis of the joint line, prevents change in the carrying angle of the elbow.

2. It places the elbow in the position whence function is most quickly and easily recovered. The mere weight of the forearm and the natural



229 230

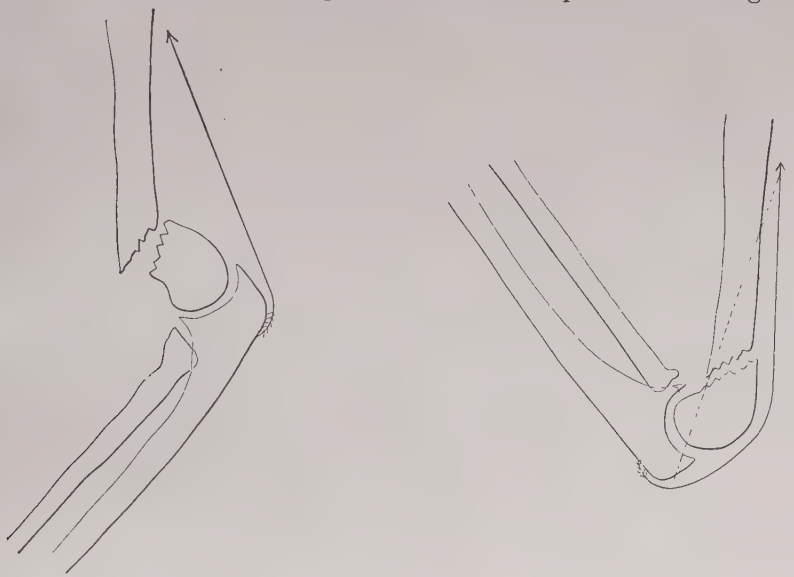
FIGS. 229 and 230.—End result of fracture of the elbow. Patient showing normal carrying angle on right and gunstock deformity on left. (Ashhurst: Fractures of the Lower End of the Humerus.)

use of the hand in lifting and carrying objects tend to restore the power of extension, with increase in the arc of motion. On the other hand, if the elbow is fixed in the position of extension, or to a lesser degree, if it be at right angle flexion, the movement of flexion is only regained by purely muscular action against the resistance of gravity. Added to this is the difficulty of stretching out the contracted triceps tendon, which is frequently bound down to the bone by scar tissue. In the position of acute flexion, it is possible to begin active motion early because the leverage on the fracture site is small. In the positions of semi-flexion and extension the leverage is great and early movement would not be safe.

3. It places the arm in the position of optimum function, if joint stiffness or limitation of motion should result. Thus, a man who can flex the elbow through an arc of 65 degrees from a position of 110 degrees

of extension can perform nearly every normal act, while if his amount of flexion remains the same but begins at a position of 165 degrees' extension, he is seriously handicapped.

Fixation.— Various methods of holding the elbow in the flexed position are available, and choice will be made of them according to the type of fracture and to what extent complete immobilization is desired. In all cases it is desirable to compress the elbow to prevent swelling. The



a *b*

FIG. 231.—Diagram showing how in the position of acute flexion the triceps muscle aids in maintaining reduction in case of a supracondyloid fracture. (a) With the elbow in extension the line of pull is posterior and causes deformity. (b) Hyperflexion. In this position the line of pull is actually anterior to the shaft of the humerus. (Ashhurst: Fractures of the Lower End of the Humerus.)

method of encircling the arm and forearm with a cuff of adhesive plaster is to be condemned because of resulting circulatory interference and congestion at the elbow (see Fig. 233). The skin should be carefully washed and powdered, particularly the anterior fold of the elbow, and a single layer of gauze should be interposed here to prevent maceration. Under no circumstance should a thicker substance be inserted, as it may cause pressure on the vessels.

Hyperflexion Bandage.— The simple method of bandaging the elbow as described by Ashhurst (Figs. 234-236), provides a very satisfactory dressing and one that is quickly and readily applied. The forearm is included in the bandage, the ends of which are left long and tied about the neck to support the wrist.

Posterior Plaster Splint.— In the more severe types of fracture, when complete immobilization is desired, a posterior moulded plaster splint may

be made of sufficient length to extend from the wrist to the shoulder. This is applied over cotton padding to the back of the arm and bandaged in place, the elbow being held in its flexed position until the plaster has hardened (Fig. 237).

Lund Swathe.—In the more simple types of fracture, satisfactory support is obtained by the use of the Lund swathe. This consists of a strip of muslin 20-24 inches wide and 5-6 feet long. It is folded on its narrow

FIG. 232.—Position of hyperflexion with small gauze fold inserted between skin surfaces at bend of the elbow.

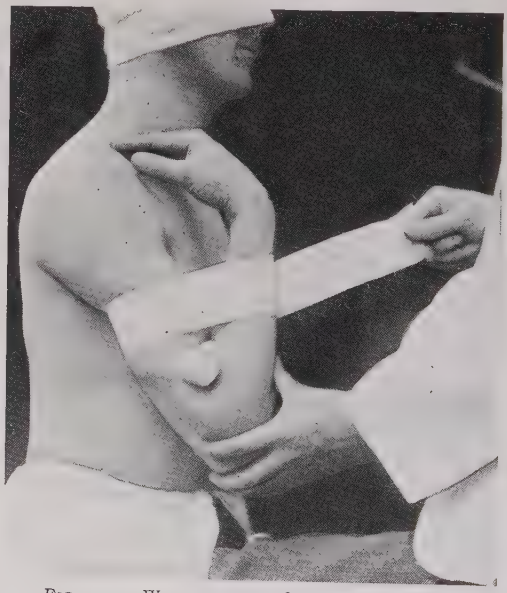


FIG. 233.—Wrong way to fix the elbow in acute flexion. The adhesive band constricts the arm and may cause serious circulatory disturbance.

width four times, giving a strip 5-6 inches wide, and is then rolled into the form of a bandage. The free end is placed on the back over the dorsal spine and held by an assistant. The bandage is then unrolled over the shoulder of the injured side and vertically downward, encircling the flexed elbow and then passing horizontally around the chest until it finally ends at the injured arm. The free ends are pulled tight and pinned to the adjacent portions of the swathe (Figs. 238–242).

Circulatory Disturbance.—After the application of the dressing, the circulation of the hand should be tested. If the radial pulse cannot be detected, the dressing must be loosened. The hand is frequently blue and congested from interference with the venous return, but this is of importance only as denoting that the case must be carefully watched. The patient should be seen within twelve hours, in every instance, to guard against the danger of circulatory interference which might follow further increase of swelling. At the end of three days, the dressing should be

234 235 236

FIGS. 234, 235 and 236.—Hyperflexion bandage. (234) The bandage commences at the wrist, one end being left long. (235) It then covers in the upper arm and elbow, the circular turns about the latter being fixed with vertical turns. (236) The dressing is completed by tying the ends of the bandage at the wrist and then knotting them about the neck. (Ashhurst: Fractures of the Lower End of the Humerus.)

opened, the skin over the front of the elbow inspected and powdered, and blebs, if present, punctured and covered with sterile gauze.

When to Begin Movement.— Of importance fully equal to that of the immediate treatment is the matter of after-treatment; when to begin motion, and how. The dangers are two-fold. On the one hand, too long immobilization permits the reparative processes in the region of the injury to bind down in scar tissue the joint capsule and neighboring mus-

FIG. 237.—Moulded posterior plaster splint. Useful in certain cases of fracture of the elbow, particularly when a position has to be used which is less than that of acute flexion.

cles and tendons. On the other hand, too early or too vigorous motion strains the callus, detaches the periosteum and small bony fragments, and leads by constant irritation either to the overgrowth of callus or the formation of bony masses in the muscles. In either case, the result is limitation of motion.

The length of time allowed to elapse before beginning motion depends upon the location of the fracture, the extent of comminution, and the completeness of reduction. It is obvious that the strain at the fracture site caused by motion will be greater if the shaft is affected than if only a small process is detached and that motion may be begun earlier in the latter than the former case. A fracture in which it has been possible to secure complete anatomical reduction will permit motion earlier than one imperfectly reduced, because, in the former case, displacement is less likely to recur than in the latter. Multiple fractures or severe comminution are also indications for a longer period of complete immobilization.

Test of Tolerance.—In general, but modified by the above considerations, motion should be begun as soon as the acute traumatic reaction has subsided. This is indicated by disappearance of pain and subsidence of swelling. A period varying from five to fourteen days is usually required. The plan to be followed is one of permitting active but limited movements of the elbow, the range of motion being gradually increased as the injured part shows itself able to tolerate it, but not exceeding this limit. The test of tolerance is the ability to continue to repeat the movement permitted after several days of use. Limitation of motion, swelling or unusual pain are signs that the limit of tolerance is being exceeded and call for a return to the use of immobilization methods.

Mobilization Dressing.—The movements should first be performed under the surgeon's own supervision with the elbow and forearm supported, but by active, voluntary effort of the patient. If, after several days' trial, no local reaction has appeared, it may be concluded that the process of union is far enough advanced to tolerate more active movement. The original dressing is now replaced by the Jones sling. This is a simple gauze bandage applied to the wrist over a layer of sheet wadding, the ends being left long and tied about the neck (Fig. 243). It supports the arm comfortably and limits extension while not interfering with flexion. By lengthening the loop about the neck, motion to any desired degree is permitted. No other dressing is necessary.

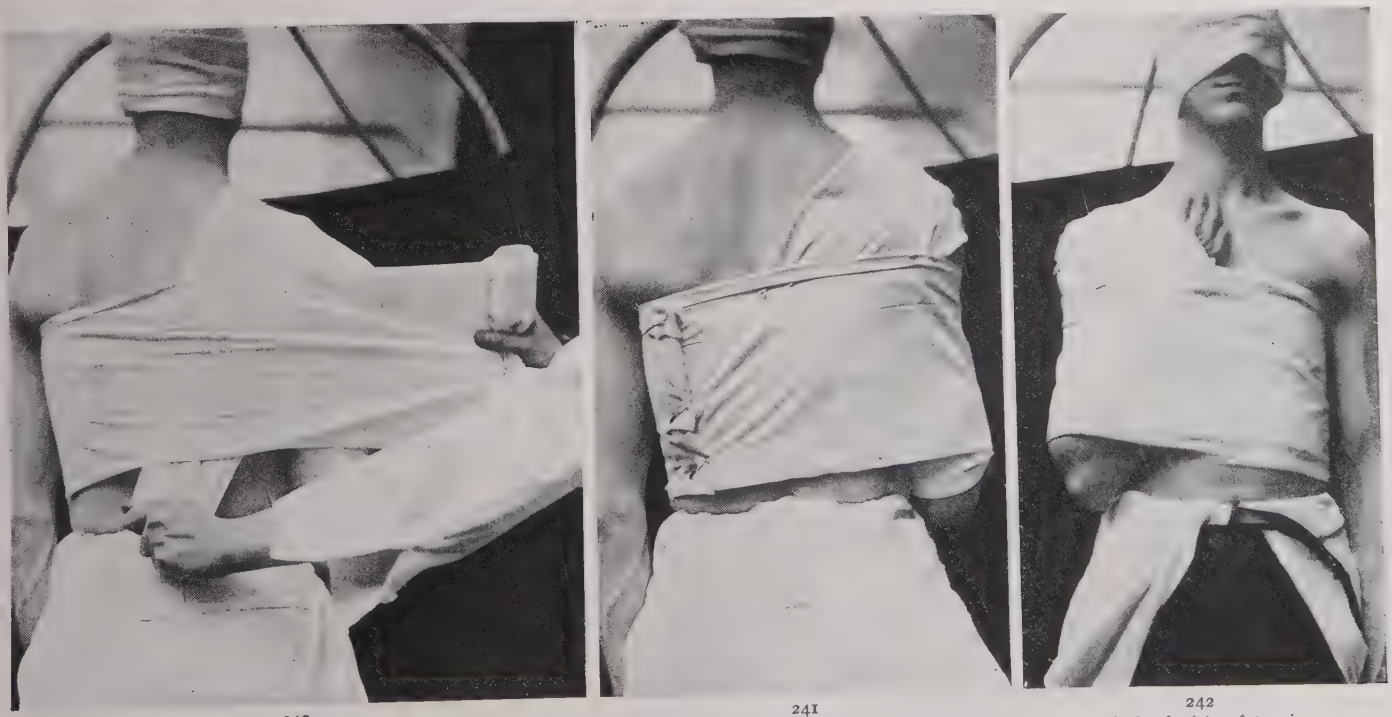
Increasing Fractional Movements.—The first position is with the hand just below the chin and the neck loop as short as possible. Only a few degrees of motion at the elbow are possible, but the patient is instructed to move the arm within this range frequently. If, after two to three days, the toleration is good, the wrist is lowered 5 cm. by lengthening the sling and thus a greater range of movement is permitted. Mobilization by gradually increasing fractional movements is continued according to this program. Every third or fourth day the wrist is lowered 5 cm., depending upon the ability of the patient to move the arm through the range of motion allowed. Local reaction means that the part is resenting the movement and is an indication for either decreasing or completely abolishing motion for a short period.

When an angle of ninety degrees is finally reached, an ordinary sling replaces the wrist sling, and active use of the arm for light tasks may be permitted. Gradually, as strength returns to the muscles and suppleness to the joints, light use changes to full use.

Baking and massage are important physiotherapeutic aids in stimulating circulation, restoring strength, and regaining motion, and should be begun as soon as the apparatus may be removed for a sufficient period to permit their use.

238 239

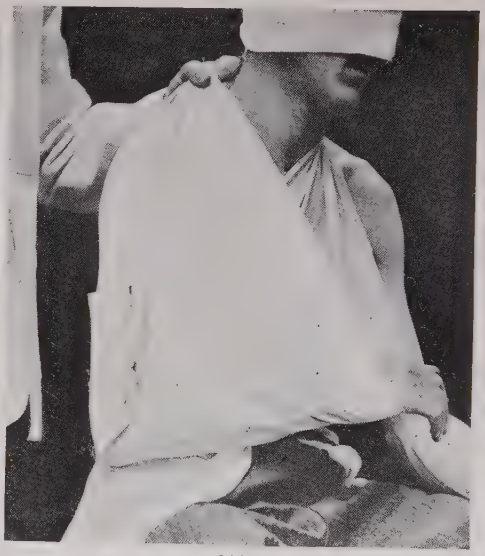
FIGS. 238 and 239.—Application of the Lund swathe. A strip of muslin 20 to 24 in. wide and 5 to 6 ft. long is folded on its narrow width four times and is rolled into the form of a bandage. (238) The free end is placed on the back over the dorsal spine. (239) The bandage is unrolled over the shoulder, under and around the affected elbow.



240 241 242

FIGS. 240, 241 and 242.—Application of the Lund swathe. (240) The swathe is then carried around the chest and the ends fixed with safety pins. (241) The completed dressing, posterior view. (242) The completed dressing, anterior view.

243



244

FIGS. 243 and 244.—Convalescent treatment of fracture of the elbow. (243) The Jones wrist sling, by means of which fractional movements of the elbow may be permitted. (244) Common type of sling which is used when the arm can be extended to a right angle.

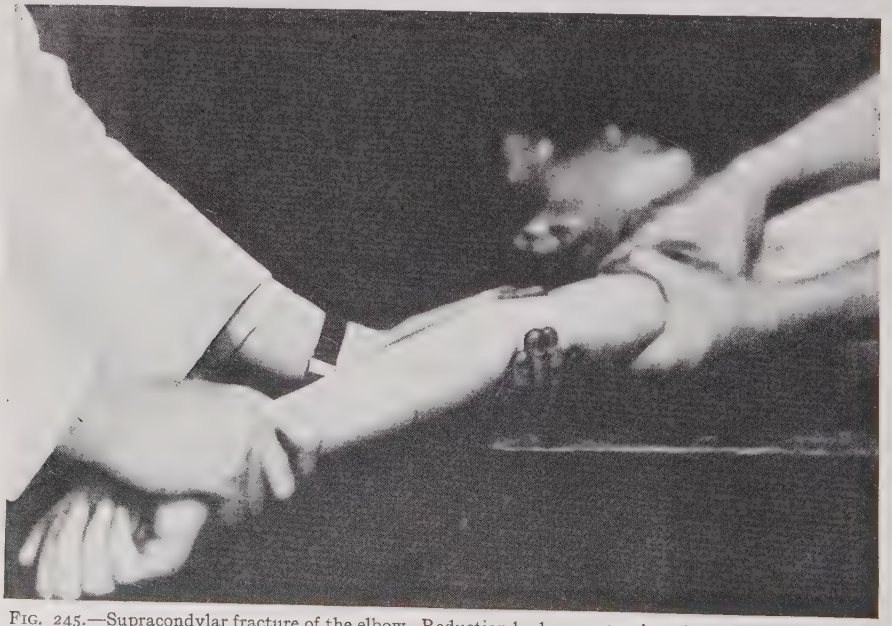


FIG. 245.—Supracondylar fracture of the elbow. Reduction by hyperextension of the elbow previous to retention in the position of acute flexion.

TREATMENT IN RELATION TO SPECIFIC FRACTURES OF THE LOWER END OF THE HUMERUS

I. SUPRACONDYLAR FRACTURE

Reduction.— The manipulation consists in repeating the steps by which the fracture was produced, only in the reverse order. This injury is typically produced by hyperextension, and the first step is to exert traction on the forearm with the elbow extended while the upper fragment is fixed by an assistant. Then force the elbow backward into hyperextension, producing angulation at the seat of fracture until the upper end of the distal fragment is felt to slip forward (Fig. 245). Then straighten the arm and flex the elbow acutely, locking the fragments in place. The

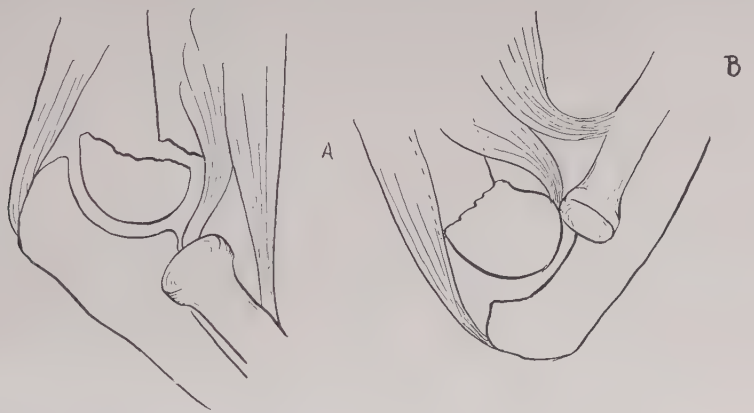


FIG. 246.—Diagrammatic representation of reduction of supracondylar fracture by position of acute flexion.

radial pulse should be palpated and comparison made with the sound side for evidence of continued displacement. If necessary, the manipulation may be repeated, but if reduction is not obtained in two attempts, it is useless to persist.

Incomplete Reduction.— In the latter case, the arm should be immobilized in a Thomas arm splint with traction on the extended forearm for a few days and the manipulation repeated at the end of this time. Reduction is often obtained in this way when not possible at first. If displacement continues and is of considerable degree, open reduction should be advised. If operation is not warranted, the elbow should be flexed and fixed in this position.

Fixation.— The arm should be immobilized in the flexed position for two weeks before beginning active motion. In children, fixation is best obtained with the "hyperflexion bandage" (see Figs. 234–236), but in adults the plaster moulded splint is preferable. (See Fig. 237.) Union is usually solid at the end of four to six weeks, and full use may be permitted at the end of six to eight weeks.

FIGS. 247, 248 and 249. Supracondylar fracture of elbow in child, aged four. (247 and 248) Anterior and lateral views before reduction. (249) Lateral view following reduction. Elbow in position of acute flexion. (Fracture Service, M. G. H.)

Prognosis.— Most cases can be completely reduced, and even when a slight degree of displacement persists, the function of the elbow is good, provided that the carrying angle is normal.

II. TRANSVERSE DIACONDYLAR FRACTURES

In cases with displacement, reduction is accomplished by the same method as in supracondylar fracture. Because of the location of the injury and the danger of resulting limitation of motion (see p. 176), it is imperative to avoid strain of the callus and stimulation of bone production by beginning movement too early. The best results are obtained by immobilizing for a period of three to four weeks, but beginning baking and massage within a few days. Fixation may be obtained by either the "hyperflexion bandage" or moulded plaster gutter splint (Figs. 234–237).

III. FRACTURE OF A SINGLE CONDYLE

Reduction should aim at as complete replacement of the fragments as possible, but the indication above all is to obtain a normal carrying angle. This is best accomplished by forcibly abducting or adducting the forearm with the elbow extended, comparing with the uninjured arm, and repeating the manœuvre if need be until normal alignment is obtained. Direct manual pressure upon the displaced condyle in a direction to correct the deformity is also of value. The elbow should then be resolutely flexed and forced into the position of hyperflexion. It may then be immobilized by the use of the plaster gutter splint or the hyperflexion bandage. Mobilization may usually be begun in ten to fourteen days, and solid union should be obtained in four to five weeks.

Open Reduction.— Certain cases with considerable displacement which cannot be reduced by conservative methods require open reduction. The approach is by a lateral incision directly over the displaced condyle. This is forced back into position and may be fixed with a screw of beef bone or steel. If a metal screw is used, it should be removed at a later date.

Prognosis.— It is never possible to exactly foretell the result in a case of fracture involving the elbow. Disappointing results, due chiefly to bony overgrowth, occur frequently enough to make the prognosis guarded in all instances. Anatomical restoration is often unobtainable, and slight limitation of motion is frequent, but if the methods of Smith and Jones are followed in detail, the functional results in the majority of cases are excellent, and useful arms are the rule.

IV. INTERCONDYLOID OR "T" FRACTURE

Reduction.— Reduction by the closed method should be attempted in all cases with displacement. The manipulation is the same as with supracondylar fracture except that the operator, in addition, should mould the condyles together by local pressure, while at the same time flexing and

250 251 252

FIGS. 250, 251 and 252.—Diacondylar fracture of the lower end of the humerus. (250 and 251) Antero-posterior and lateral views before reduction. (252) Antero-posterior view following reduction, retention being obtained by traction with the elbow at right angle flexion, the position of acute flexion being impossible on account of the large amount of swelling and circulatory disturbance. (Fracture Service, M. G. H.)

extending the elbow and exerting traction. The arm should then be immobilized in acute flexion with the posterior moulded plaster splint.

Traction Methods.— In certain cases, when reduction has been obtained, the deformity recurs when the elbow is flexed. Such cases should be treated by traction, either in the modified Jones humerus splint (Fig. 141), or according to the traction suspension method of Blake [4] with the elbow in the position of right angle flexion (Figs. 254, 255). In both cases movement at the elbow should be begun early without removing the traction.

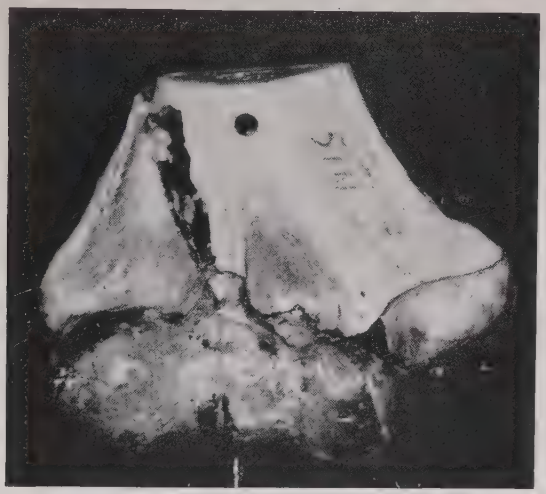
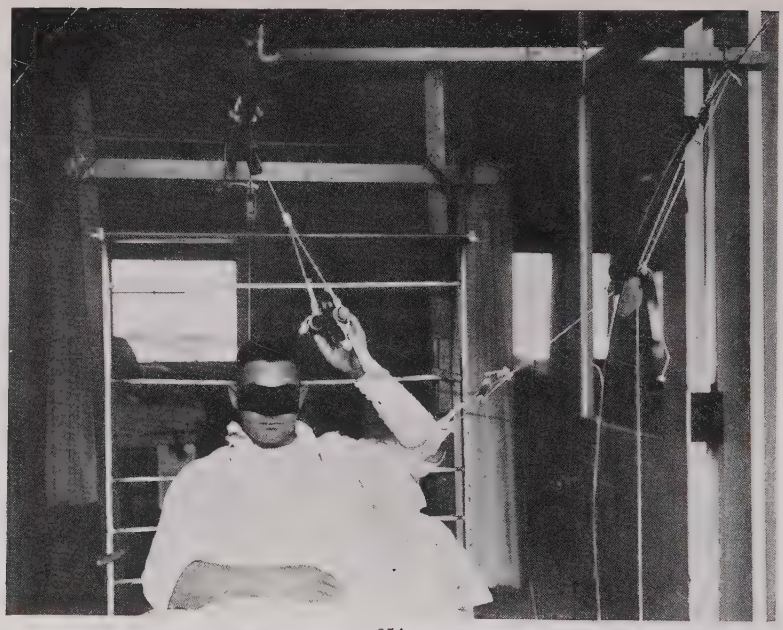


FIG. 253.—Fracture of internal condyle continuing below through line of epiphyseal junction.

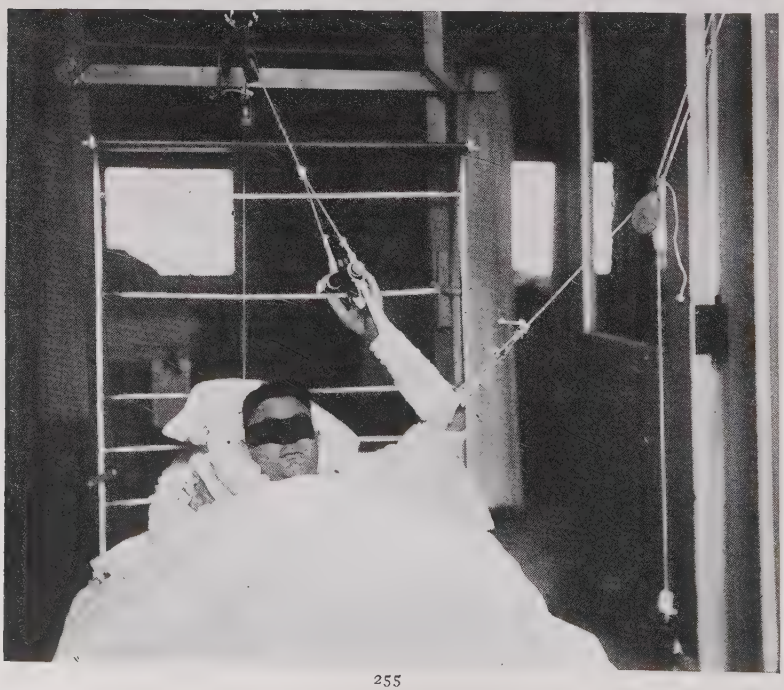
Open Reduction.— In general, the less the comminution and the better the reduction, the better the function. Some intercondyloid fractures are attended by extraordinary displacement of one of the fragments. It may be entirely separated and lie in front of the joint or it may be completely rotated on its transverse axis. It is obvious that in such cases only operative exposure of the joint with direct replacement of the fragments will offer any hope of function. In such cases operation should be resorted to early, and they should not be needlessly traumatized by attempted reduction when this is certainly foredoomed to failure.

Exposure may be obtained by incisions along the mesial and lateral aspects of the condyles, or if this is not likely to be sufficient, the posterior incision of Langenbeck may be used. The soft structures covering the condyles on either side are raised as subperiosteal flaps, thus giving a view of the entire posterior surface of the back of the humerus. The condyles are screwed together, the incision closed, and the arm immobilized in acute flexion, which secures replacement of the articular end of the bone with respect to the shaft.

[4] J. A. Blake, *Gunshot Fractures of the Extremities,* Masson et Cie., Paris, 1918.

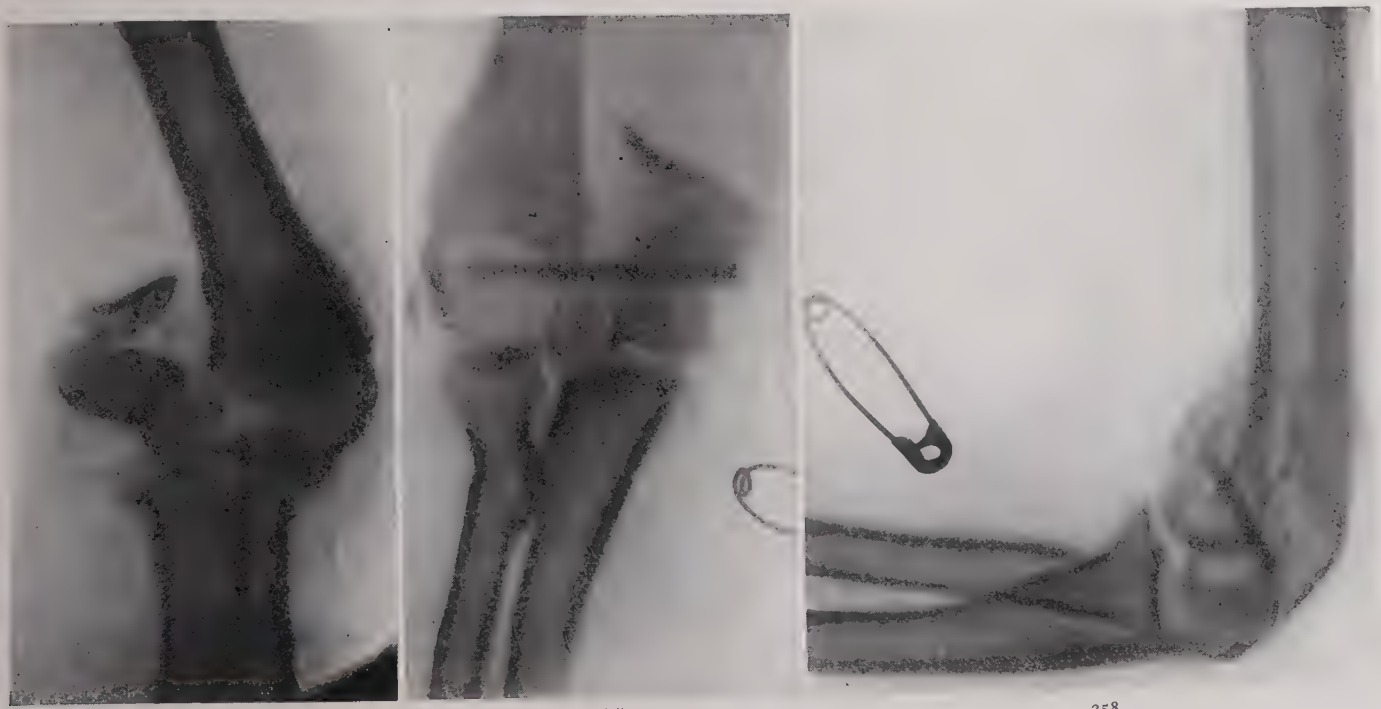


254



255

FIGS. 254 and 255.—Comminuted fracture of the lower end of the humerus. Method of suspending the arm by two-way traction and suspension, allowing the early inauguration of active motion. (254) Patient sitting. (255) Patient lying.



256 257 258

FIGS. 256, 257 and 258.—Comminuted intercondyloid fracture. (256) Before reduction. Note the tipping upward of the articular surface of the internal condyle. (257 and 258) Antero-posterior and lateral views following open reduction and fixation with long beef-bone screw. Good functional result. (Fracture Service, M. G. H.)

V. FRACTURE OF AN EPICONDYLE

This is a minor injury in most cases and practically never leads to permanent disability or deformity, except when the fracture line enters the joint. In the latter case, the only possibility for danger lies in too long fixation. Manipulative reduction is rarely necessary. If the elbow

FIG. 259.—Separation of the capitellar epiphysis. Reduction has been attempted but unsuccessfully. The roentgenogram has been made in the antero-posterior plane and the elbow is in the position of acute flexion. Note how the epiphyseal centre has turned completely upside down. Open reduction indicated. (Fracture Service, M. G. H.)

can be acutely flexed no anæsthetic is necessary, and the arm may be immobilized immediately with the "Lund swathe" (Figs. 238 to 242). Graded fractional movements should be begun at the end of four to five days, and union should be solid in three to four weeks.

VI. EPIPHYSEAL SEPARATION

Reduction.—The displacement in these cases should be corrected by manipulative reduction the same as in fracture of a single condyle, and followed by immobilization in the position of acute flexion by means of the "hyperflexion bandage" (Figs. 234–236), or "Lund swathe" (Fig. 238).

Special stress during the reduction should be laid upon local pressure on the fragment combined with flexion and extension of the elbow and traction. The best proof that replacement has been obtained is the ability to obtain complete flexion of the elbow.

Open Reduction.—Evidence of failure to obtain reduction is best obtained by a roentgenogram made in the antero-posterior plane with the elbow acutely flexed. The position of the osseous centre of the epiphysis is well shown in this view (Fig. 259). If displacement persists following

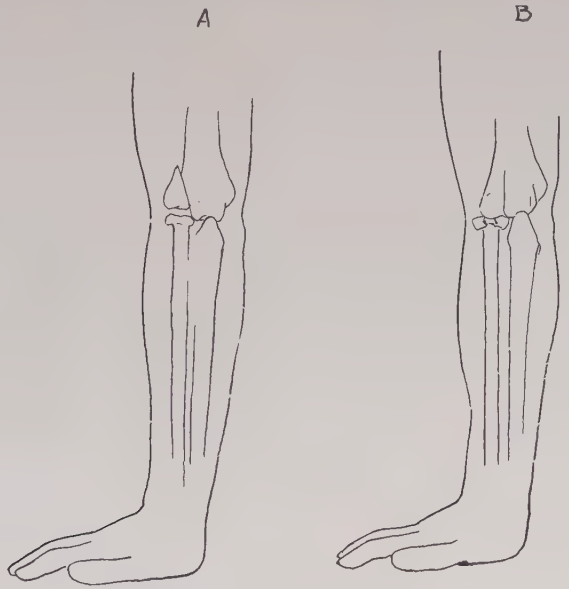


FIG. 260 (A, B).—Types of injury which may result from a fall on the outstretched hand, the force being transmitted upward in the axis of the radius. (A) Fracture of the external condyle or capitellum. (B) Fracture of the head of the radius.

manipulation, open reduction is advisable and should be performed within four to five days of injury. Callus is quickly formed and its presence interferes with accurate replacement. A lateral incision provides the exposure, the fragment is freed, pushed back into position, and retained by acute flexion of the elbow. With operation at a later period, internal fixation by means of a steel pin is apt to be required.

III. FRACTURES OF THE HEAD AND NECK OF THE RADIUS

Mechanism.—This injury occurs almost altogether in adults, and is usually the result of severe trauma. It is frequently associated with other fractures of the elbow. It may result from force applied to the hand and transmitted upward in the long axis of the forearm, the elbow being slightly flexed. The radius is thrust against the capitellum with

resultant splintering of the head (Fig. 260). In other cases the injury results from a direct blow on the elbow.

Pathology.—The neck of the radius may be fractured and the head dislocated forward from the orbicular ligament, or there may be impaction without displacement. Small fragments may be chipped from the head without accompanying fracture of the neck. The usual thing is to find comminution of the head associated with fracture of the neck and considerable displacement of some of the fragments.

Diagnosis.—The diagnosis is based on the presence of joint effusion, marked tenderness over the radial head, and limitation of the movements

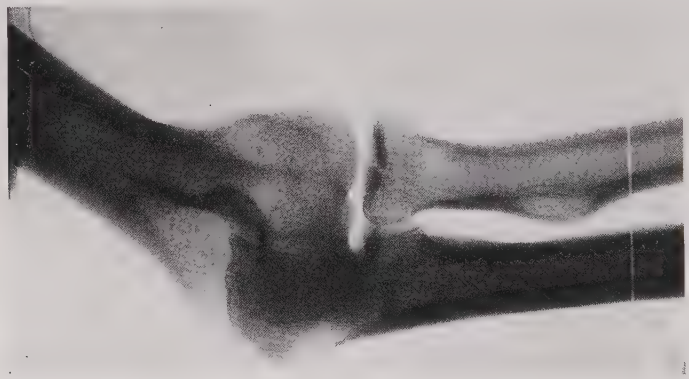


FIG. 261.—Fracture of the head of the radius. Small crack through head of the bone; no displacement. This was treated with minimal fixation and early movement. Recovery was perfect at the end of four weeks.

of supination and pronation, with pain on attempted motion referred to the site of injury. Crepitus is usually elicited on rotation of the forearm, and failure of the head to accompany the shaft in this movement can occasionally be demonstrated.

Treatment.—From the standpoint of treatment, the cases must be divided into those with displacement and those without displacement. The latter group presents no especial problem. The elbow should be flexed acutely, and the forearm supinated, anæsthesia being unnecessary. Immobilization by means of the "hyperflexion bandage" or "Lund swathe" should be maintained for seven to ten days, when a sling may be substituted. Baking, massage, and gentle supported movements of the forearm and elbow should be utilized from the first day, and gradually increased. Light use should be encouraged at the end of two weeks, and full use at the end of three to four weeks.

Fracture with Displacement.—In the case of fracture with displacement, one must choose between the conservative and operative methods of treatment. With the head of the bone or a large fragment displaced forward so that it interferes with motion, excision of the wandering piece of bone at an early date offers the best solution (see Figs. 210-212). With extensive comminution of the head, or in cases with only slight displacement,

the closed method of treatment is usually best. In the former condition, it is extremely difficult to remove all fragments by operation and the trauma resulting from the attempt may stimulate bone production and lead to a condition resembling myositis ossificans. On the other hand, the end results of conservative treatment are often surprisingly good in apparently hopeless cases. If slight limitation of rotation of the forearm persists, the functional loss is slight, the patient compensating by rotation of the shoulder and increased flexibility of the wrist. Most important of all, a true estimate of the disability may be obtained, and when this is con-

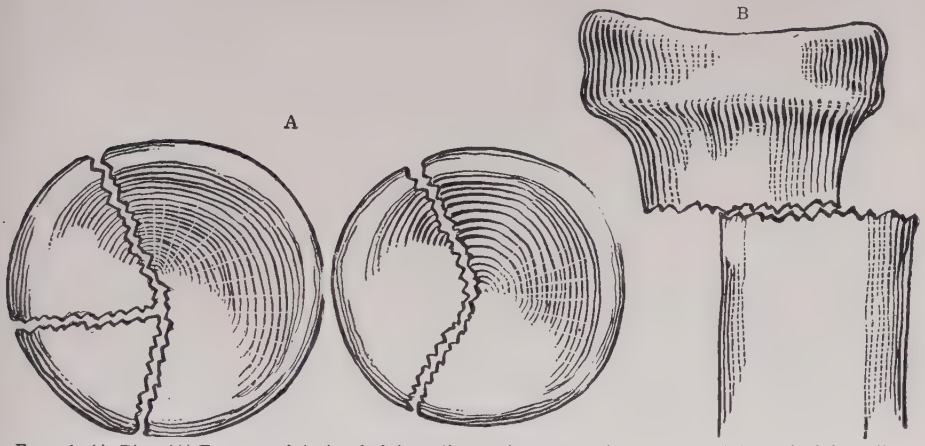


FIG. 262 (A, B).—(A) Fracture of the head of the radius, various types. (B) Fracture of the neck of the radius.

siderable, excision of the head of the bone may be performed with better prospect of restoring function. In general, the latter operation should be reserved for those cases in which the limitation of motion prevents the resumption of the normal occupation, and where the work is not particularly heavy.

When the conservative method is to be followed, the plan is the same as in the cases of fracture without displacement except that anæsthesia may be required to force the elbow into the position of acute flexion on account of blocking fragments which must be pushed aside. Fixation should be more complete, and movement should not be permitted until the end of two weeks.

Excision of the Radial Head.— Operative exposure of the head of the radius is gained by an incision directly over its posterior aspect. A lateral incision is dangerous on account of the situation of the posterior interosseous nerve. When operation is performed early, simple removal of the displaced fragment is all that is necessary. When performed only after union has occurred, the entire upper end of the bone should be excised, including a portion of the neck. Following the operation, the arm should be immobilized in a sling and active movement begun in three to four days.

IV. FRACTURE OF THE CORONOID PROCESS

Nature of the Lesion.— This injury rarely occurs alone. It is most commonly associated with posterior dislocation of the elbow, since the coronoid process constitutes a check to posterior displacement of the ulna. The fracture line runs from the anterior part of the greater sigmoid cavity, forward, separating only a small fragment. This piece, because of its attachment to the brachialis anticus muscle, may be considerably displaced

FIG. 263.—Fracture of the neck of the radius; slight impaction with scarcely any displacement; good functional result.

in an upward direction (Fig. 267), particularly when the elbow is extended. The diagnosis usually can be made only from a radiogram.

Treatment.— Approximation of the fragments is readily secured by placing the elbow in the position of acute flexion. Fixation should be as complete as possible, and the moulded posterior plaster splint is to be preferred. Movement of the elbow ought not to be permitted for a period of three weeks, if bony union is to be obtained. Massage may be begun immediately, the splint being removed daily for this purpose. Complete recovery without functional loss may be expected in five to seven weeks.

V. FRACTURE OF THE OLECRANON

Mechanism.—Fracture of the olecranon may occur at any age, but is most common in adults. Rarely it may be produced by a direct blow, but more frequently is the result of a combination of muscular action and indirect violence, as in the case of a fall on the outstretched but semi-flexed

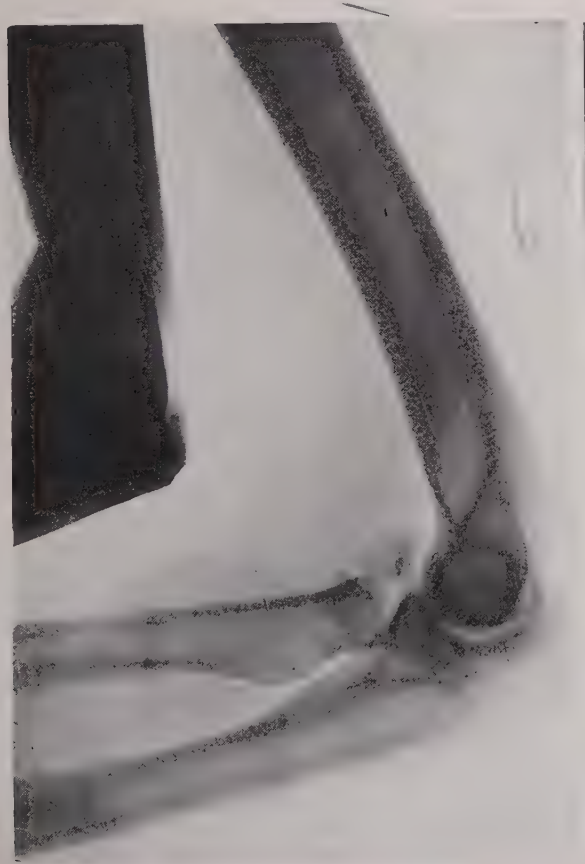


FIG. 264.—Comminuted fracture of the head of the radius with marked displacement. Excision required.

FIGS. 265 and 266.—Fracture of the neck of the radius with gross displacement of head. Excision required. (265) Antero-posterior view. (266) Lateral view. (Fracture Service, M. G. H.)

arm (Fig. 268). At the moment of impact, the muscles of the arm, and more particularly the triceps, are tense from the effort to ward off injury.

FIG. 267.—Fracture of the coronoid process showing upward displacement from the action of the brachialis anticus muscle.

The effect of the blow is to produce flexion of the elbow against muscular resistance, and the olecranon, being the weak point, gives way. A few

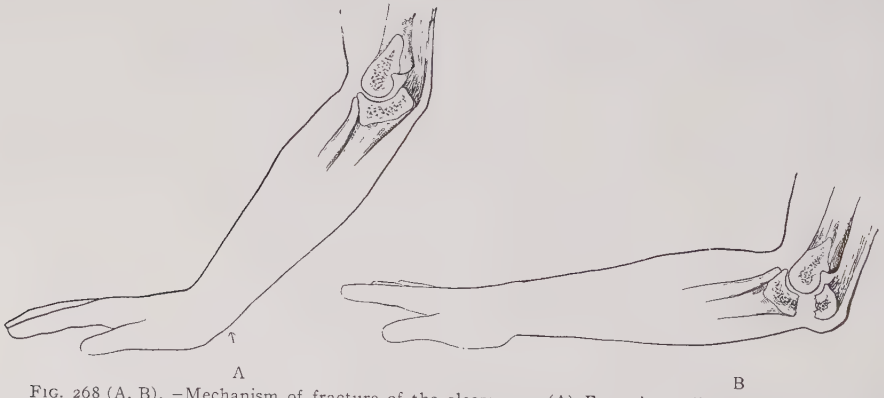


FIG. 268 (A, B). —Mechanism of fracture of the olecranon. (A) Force is applied to the forearm in a direction to cause flexion, the tip of the olecranon being fixed by the triceps. (B) The olecranon process proves the point of least resistance and gives way.

cases of fracture by muscular action alone have been reported, but this is very rare.

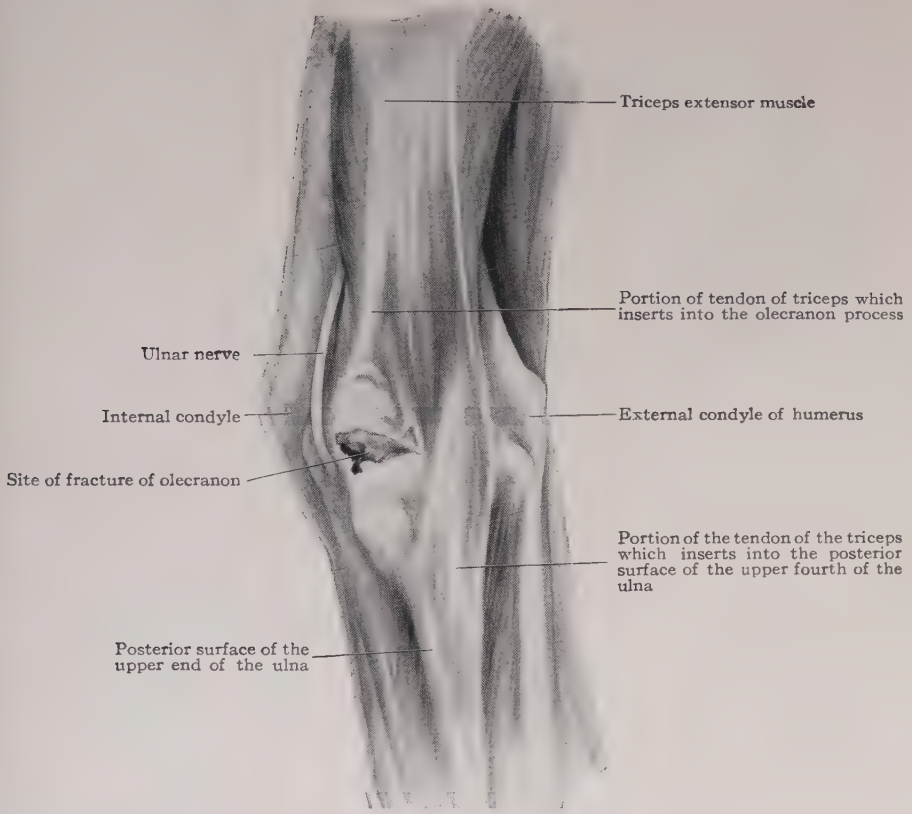


FIG. 269.—Anatomical dissection of a case of fractured olecranon showing the limiting influence on displacement of the lateral expansion of the triceps muscle. (Davis: Applied Anatomy.)

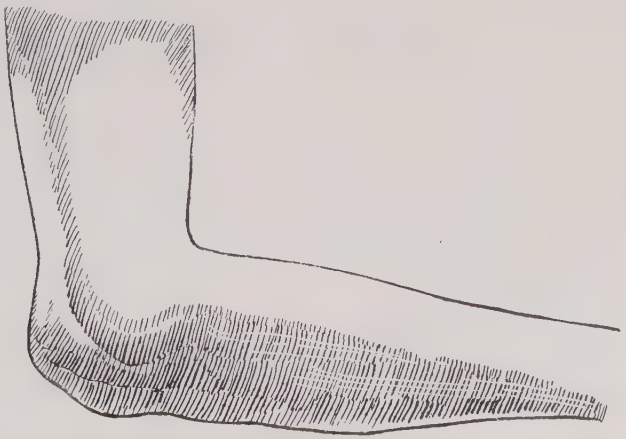
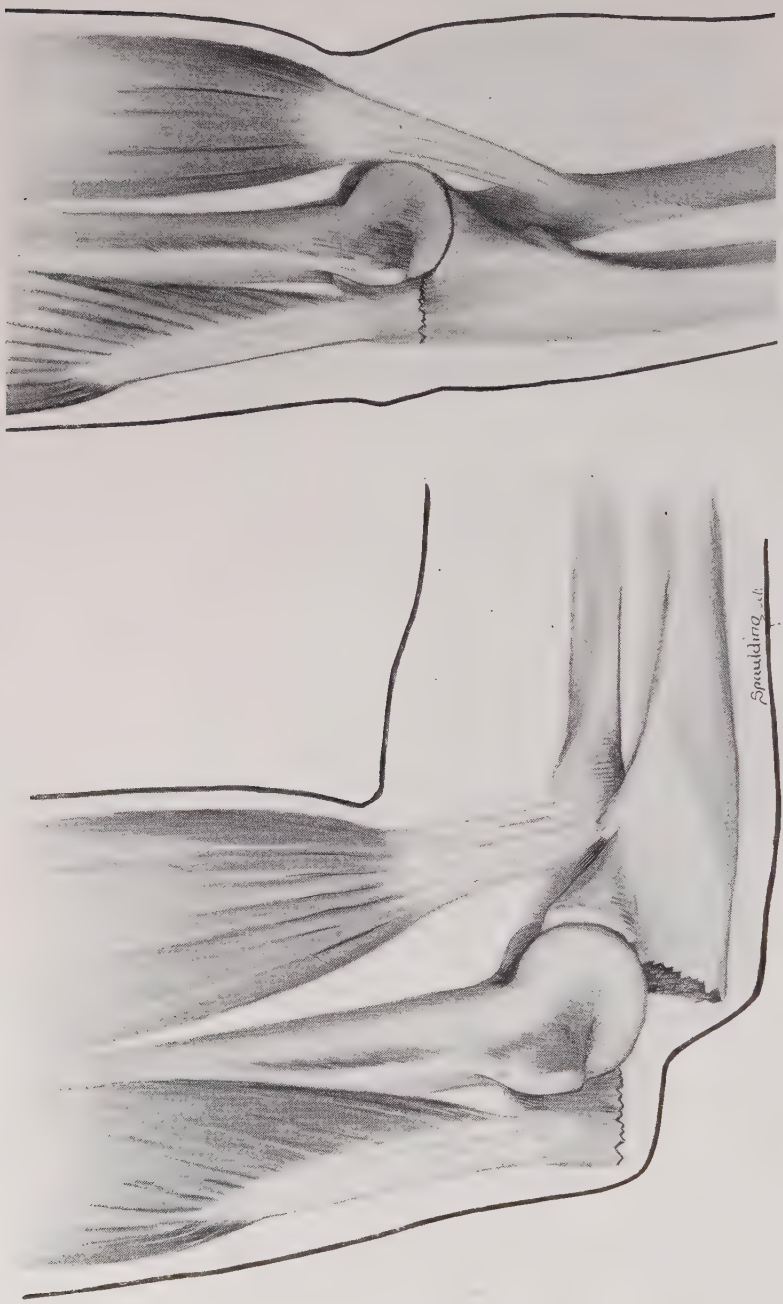


FIG. 270.—Characteristic deformity in fracture of the olecranon. Note the surface depression corresponding to the gap between the fragments.



271 272

FIGS. 271 and 272.—Treatment of fracture of the olecranon. (271) Separation of the fragments from action of the triceps, particularly noted when elbow is flexed, (272) Approximation secured by the position of extension.

Pathology.—Usually the fracture line is transverse and penetrates directly into the greater sigmoid cavity at about its middle, but it may involve only the proximal portion of the process. Comminution is very rare. There is usually an accompanying tear of the portion of the triceps insertion overlying the seat of fracture, and this may extend transversely on either side into its fibrous lateral expansions. The degree of separation of the fragments directly depends upon the extent of this lateral tear. It

FIG. 273.—Anatomic specimen of comminuted fracture of the olecranon. (Warren Anatomical Museum.)

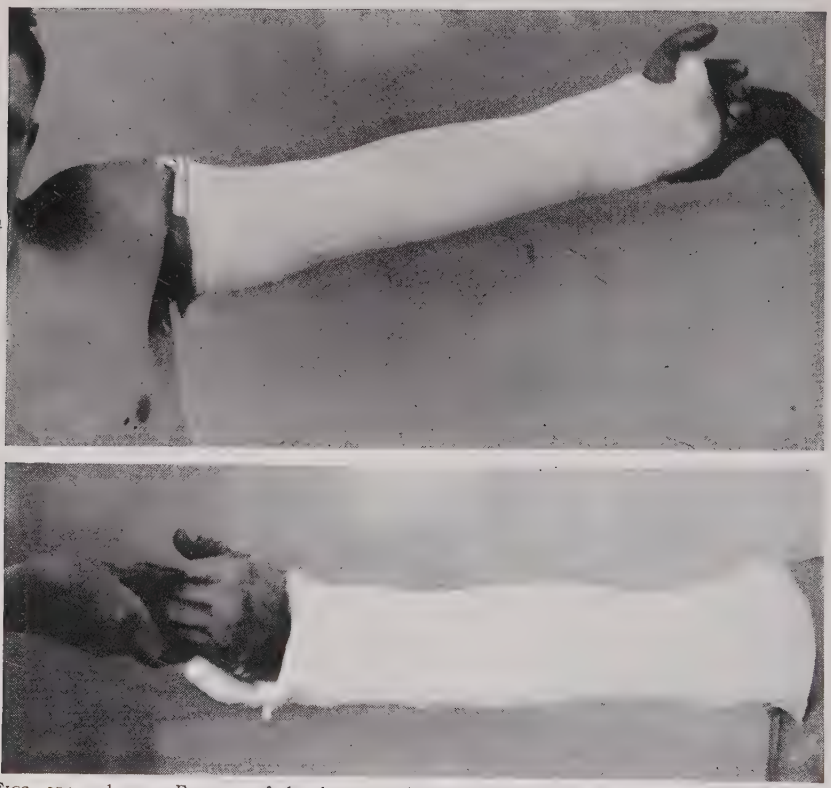
is rare to have separation of more than 1.25 to 2 cm. and there may be none.

Diagnosis.— The arm is usually held slightly flexed, and there is inability to control the movement of extension. There is effusion in the elbow-joint and usually a prominent soft swelling over the seat of injury. If there is displacement of the olecranon, a definite sulcus can be made out between the fragments. In the absence of displacement, there is sharply localized tenderness over the line of fracture. The diagnosis rarely presents any difficulty, but it is always advisable to have the roentgenological evidence in addition to the clinical findings.

Treatment.— The indications for treatment are definite. In the presence of separation of the fragments, approximation can be obtained only by complete extension of the elbow. If replacement is not accomplished by this means, pressure may be exerted upon the olecranon to force it down into position, and if this is successful, it may be fixed by crossed

adhesive strapping with a soft pad over the bony prominence to prevent injury of the skin. In the cases of fracture without displacement, the position of extension is also necessary to relax the triceps and prevent possible later separation.

Fixation.— Anæsthesia is unnecessary. The elbow is extended and, if there is separation of fragments, the olecranon is pushed down and fixed.



274

275

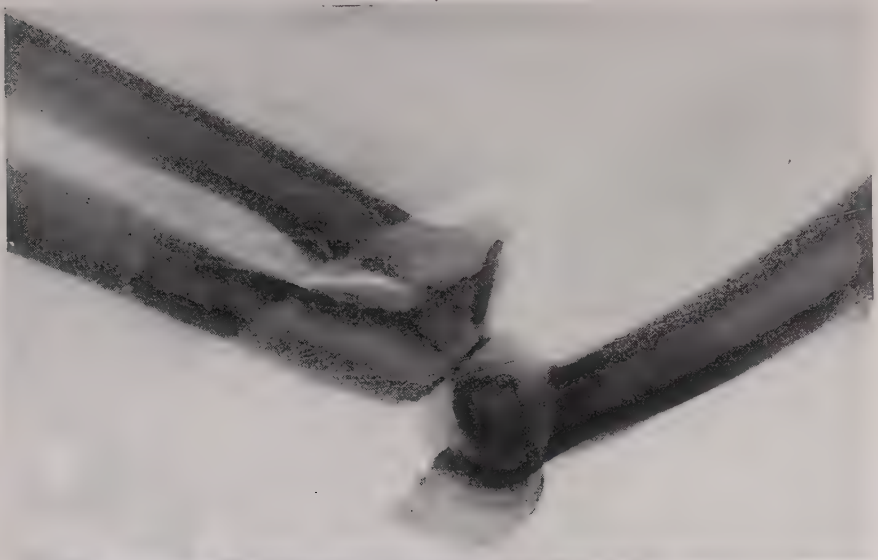
FIGS. 274 and 275.—Fracture of the olecranon. Plaster casing applied securing fixation in position of complete extension. Note the wrist support holding the wrist dorsally flexed and leaving the fingers free. (274) Anterior view. (275) Posterior view.

In the absence of displacement, elbow flexion of 15-20 degrees may be permitted, and this usually gives greater comfort. Fixation in both cases is best obtained by a plaster cast extending from the metacarpo-phalangeal articulation to the axilla.

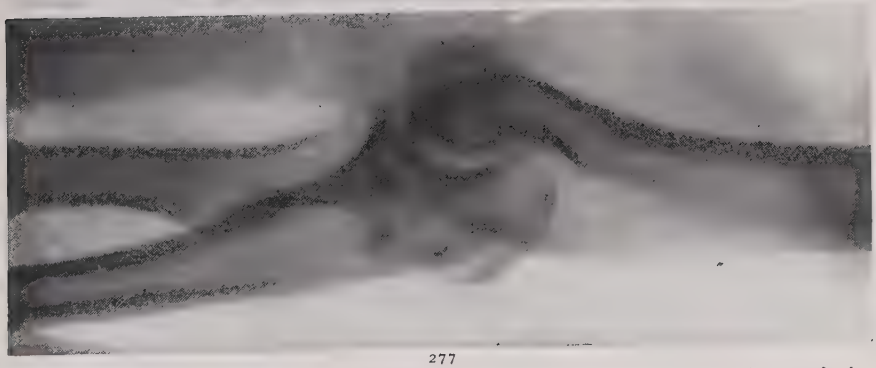
The plaster cast should be split immediately, and the arm lifted out daily for massage about the elbow. At the end of two weeks, active motion may be begun, but should not be allowed to exceed an arc of 45 degrees. At the end of three to four weeks the range of flexion should be increased, and a sling substituted for the cast. At the end of five to six weeks, union is usually solid, and after six to eight weeks full use may be permitted.

Open Reduction.—Unless complete approximation of the fractured surfaces is obtained, union is apt to be fibrous rather than bony. Almost perfect functional recovery is occasionally seen in cases with wide separation of fragments and fibrous union. A period of many months is neces-

276



277



FIGS. 276 and 277.—Fracture of olecranon with forward dislocation of both bones of the forearm. (276) Before reduction. (277) Following reduction and suture of olecranon. (Fracture Service, M. G. H.)

sary for such recovery, but the fact that it does occur should counsel prudence and conservatism in the treatment of aged patients or of those whose occupation requires only light work. Nevertheless, in young, healthy adults in whom recovery of full strength of the elbow is essential and the time element important, approximation of the fragments through an open incision should be resorted to whenever it cannot be secured by other methods.

The fracture may be approached by a linear incision directly over the olecranon. Fixation of the fragment may be obtained by a beef-bone screw or by suture with wire or kangaroo tendon. Our own preference is for the use of absorbable material. An important point in the operation is to expose the lateral expansions of the triceps and repair the transverse tear in these structures. After closure, the arm is fixed in extension by

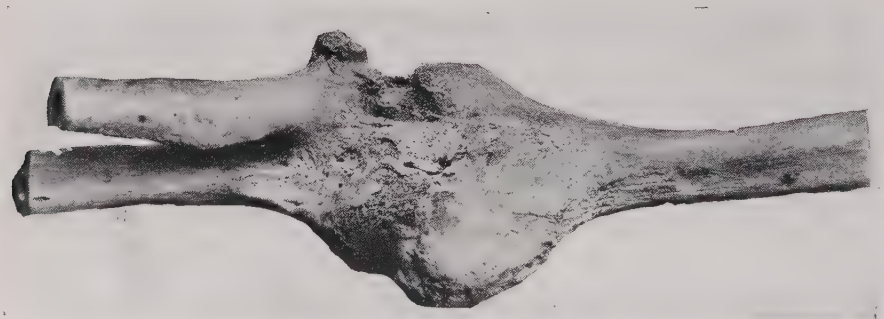


FIG. 278.—Old compound fracture of the elbow. This specimen shows complete ankylosis of all three bones. (Army Medical Museum.)

the use of plaster, and the after-treatment is the same as with the closed method.

COMPOUND FRACTURES OF THE ELBOW

With a careful débridement operation and reduction of the fracture, it is often possible to close the wound by primary suture and splint the limb as in a simple fracture. If the wound has to be treated by the open method, a more suitable mode of fixation is by Blake's method of traction. The patient is put to bed, and, the arm being abducted and the forearm flexed to a right angle, traction-strips are applied to the latter and connected to an overhead weight-and-pulley apparatus. A band of sterile flannel 7.5 cm. broad is passed over the front of the forearm near the elbow and traction exerted over the side of the bed by weight and pulley. This means of fixation permits of easy access to the wound and, while maintaining alignment, allows a certain amount of motion of the articulation.

CHAPTER VIII

THE FOREARM

I. FRACTURE OF THE SHAFT OF THE ULNA

II. FRACTURE OF THE SHAFT OF THE ULNA, ASSOCIATED WITH DISLOCATION OF THE HEAD OF THE RADIUS

III. FRACTURE OF THE SHAFT OF THE RADIUS

IV. FRACTURE OF BOTH BONES OF THE FOREARM

ANATOMICAL CONSIDERATIONS

Ulna.—The shaft of the ulna tapers progressively from its enlarged upper end towards its distal rounded extremity. Its dorsal surface is straight and subcutaneous throughout and produces a furrow in the contour of the arm which is particularly noticeable in muscular subjects. This superficial position permits palpation of the bone, and changes in contour due to fracture are readily recognizable. For the same reason fractures of the ulna are frequently compound.

Radius.—The enlarged end of the radius is at the distal extremity. Above this the shaft diminishes in size toward the head. The proximal third is covered by a thick layer of muscles and is ordinarily not palpable; below this point the covering is tendinous and the situation superficial.

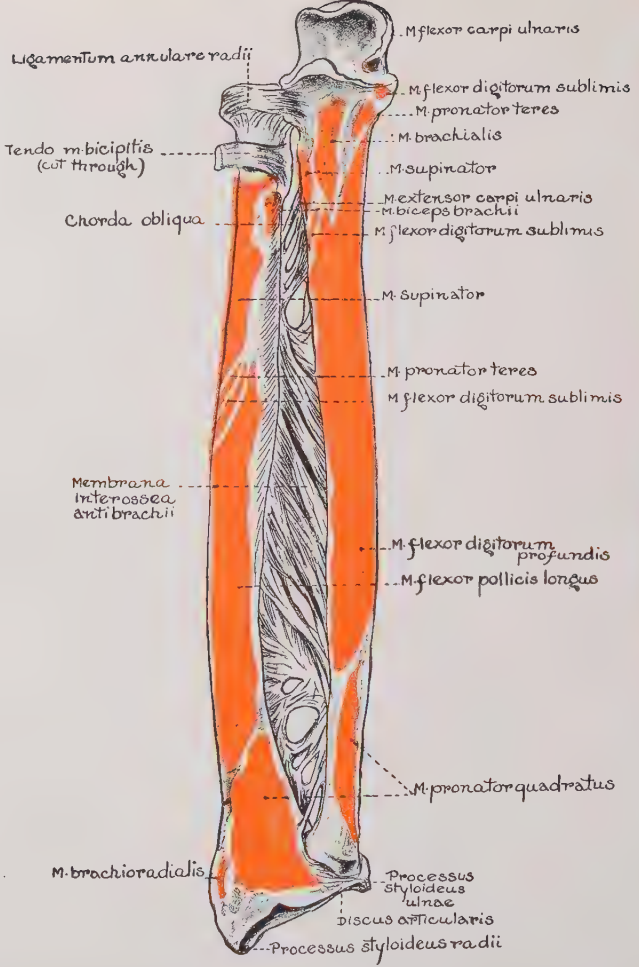
An important feature of the radius is the convexity of its shaft (Figs. 279, 280). Beginning just below the neck, the curve is outward to mid-shaft, then inward and slightly forward. This bow is necessitated by the eccentric relationship between the axes of the superior and inferior radio-ulnar joints. In movements of pronation and supination, the motion of the superior radio-ulnar articulation is one of rotation of the radius in the axis of its head. At the inferior radio-ulnar joint the ulna is the fixed point about which the lower end of the radius swings, with the axis of motion at the root of the ulnar styloid. The curve in the radial shaft compensates for this arrangement of the joints and permits the radius to swing across the ulna in pronation, without impingement. Flattening of the curve following fracture causes mechanical interference by the ulna with the movements of the radius and limits rotation of the forearm.

Interosseous Membrane.—The radius and ulna are bound together by a strong fibrous sheet, the interosseous membrane. It extends from the inner border of the radius to the outer border of the ulna and completely closes the gap between the two bones, with the exception of a small triangular area at the proximal end. Its fibres run chiefly downward and inward and are so arranged as to maintain tension in all positions of rotation. In fractures of the bones of the forearm it prevents separation of the radius from the ulna; the interosseous space is frequently narrowed, but never widened.

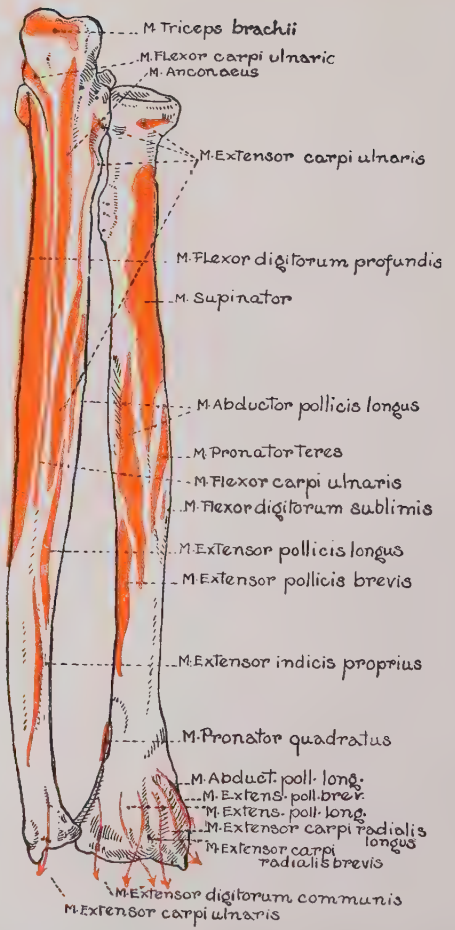
The direction of the fibres of the interosseous membrane permits the conduction of force transmitted upward through the radius across to the ulna. Since the hand articulates through the carpus with the radius but not at all with the ulna it will be seen that indirect violence from a fall on the hand may cause fracture of the radius with fracture of the ulna, but not fracture of the ulna alone.

The amount of possible rotation of the forearm rarely exceeds 160 degrees. Supination is limited chiefly to tightening of the inferior anterior radio-ulnar ligament, while pronation is checked by the inferior posterior radio-ulnar ligament. (For a description of the superior and inferior radio-ulnar articulations, see page 157 and page 250.)

Interosseous Space.—On account of the possibility of bony union or synostosis occurring between the ulna and radius in cases of fracture, the relation of the bones



279



280

FIGS. 279 and 280.—The bones of the forearm. Muscle attachments shown in red. (279) Anterior view showing interosseous membrane. (280) Posterior view.

to each other in various positions of rotation is important. In the position midway between pronation and supination the bones are most nearly parallel and at the greatest distance from each other (see Fig. 281). In the position of full supination the middle portions of the shafts are as far apart but the proximal portions approach each other. In full pronation the radius crosses over the ulna and there is least separation of the bones. As fracture of both bones in the proximal third is rare it will be seen that either the

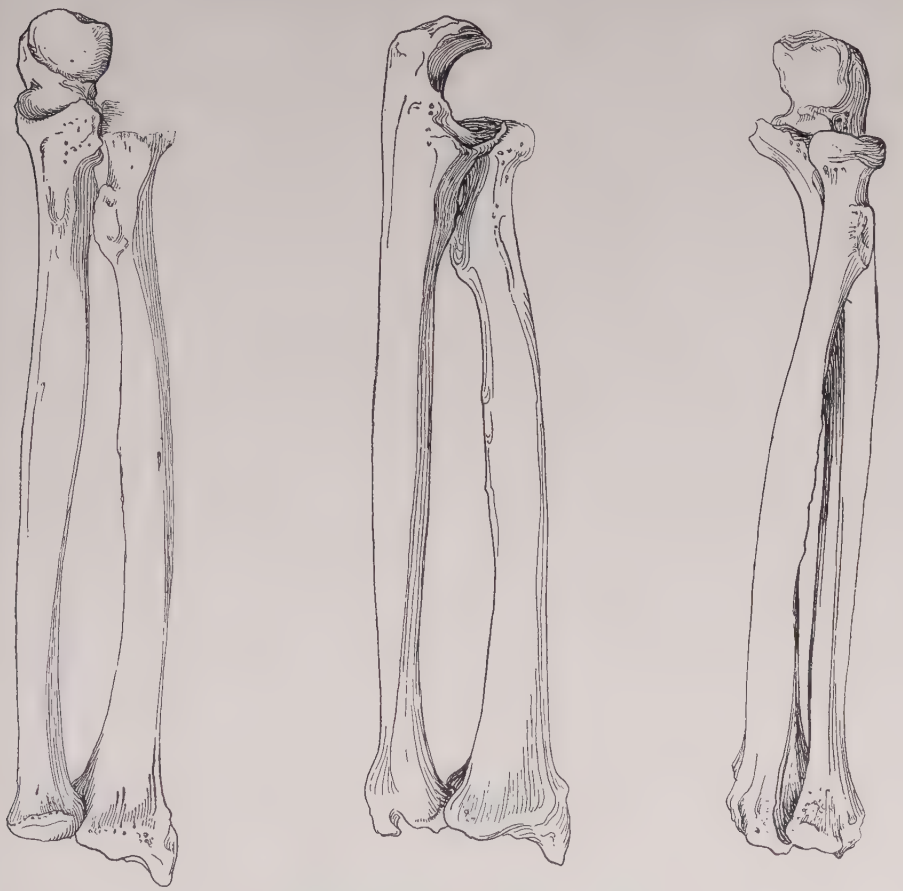


FIG. 281.—Drawings showing relations of the radius and ulna, and the width of the interosseous space in the positions of (A) supination, (B) mid-supination and (C) pronation.

positions of full supination or semi-pronation are least conducive to synostosis while that of full pronation is most likely to result in it.

Muscles of the Forearm.—The superficial group of flexor and pronator muscles arises mainly from the mesial condyle of the humerus. They pass obliquely down the forearm and with the exception of the flexor carpi ulnaris and a portion of the flexor profundus digitorum are all supplied by the median nerve. The main group of extensor muscles takes origin chiefly by means of a common tendon from the external condyle of the humerus and receives its nerve supply from the posterior interosseous nerve.

Pronation is performed by the pronator radii teres and pronator quadratus muscles. The former arises by two heads from the mesial condyle of the humerus and the coronoid process of the ulna and is inserted at the middle of the shaft of the radius.

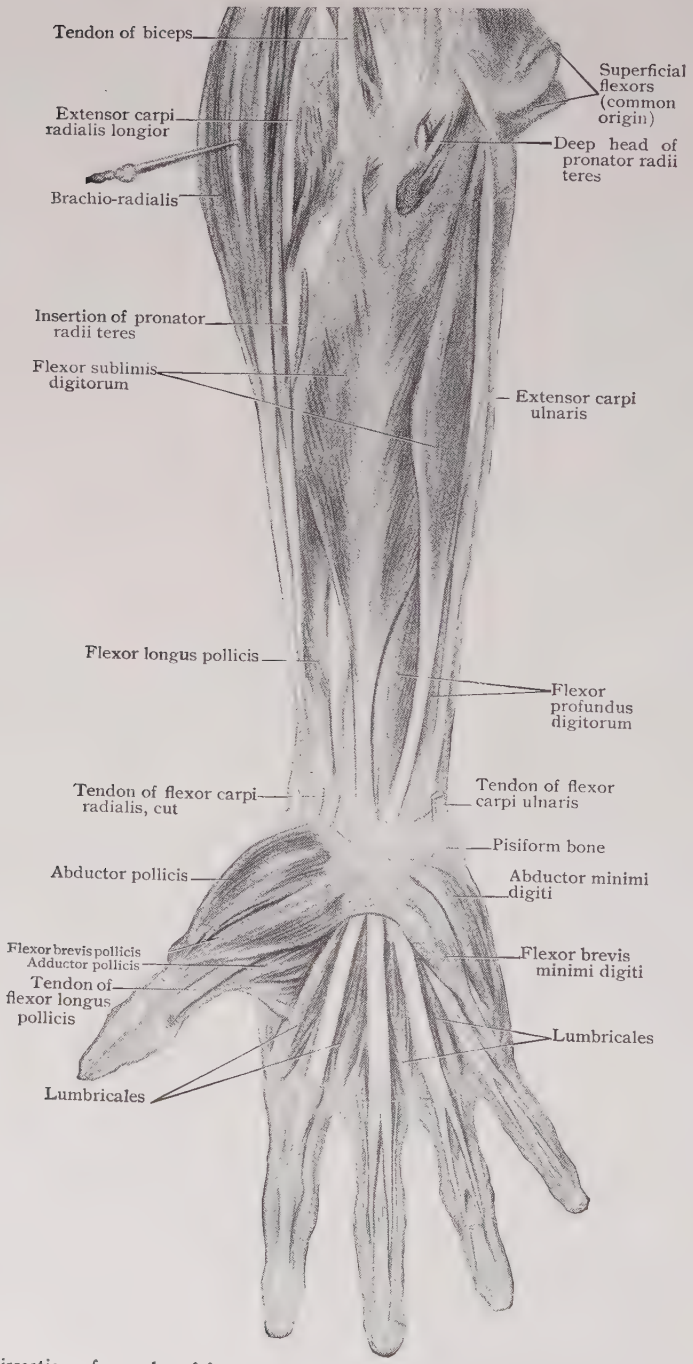


FIG. 282.—Dissection of muscles of forearm and hand, anterior surface; most superficial muscles have been removed. (Piersol: Human Anatomy.)

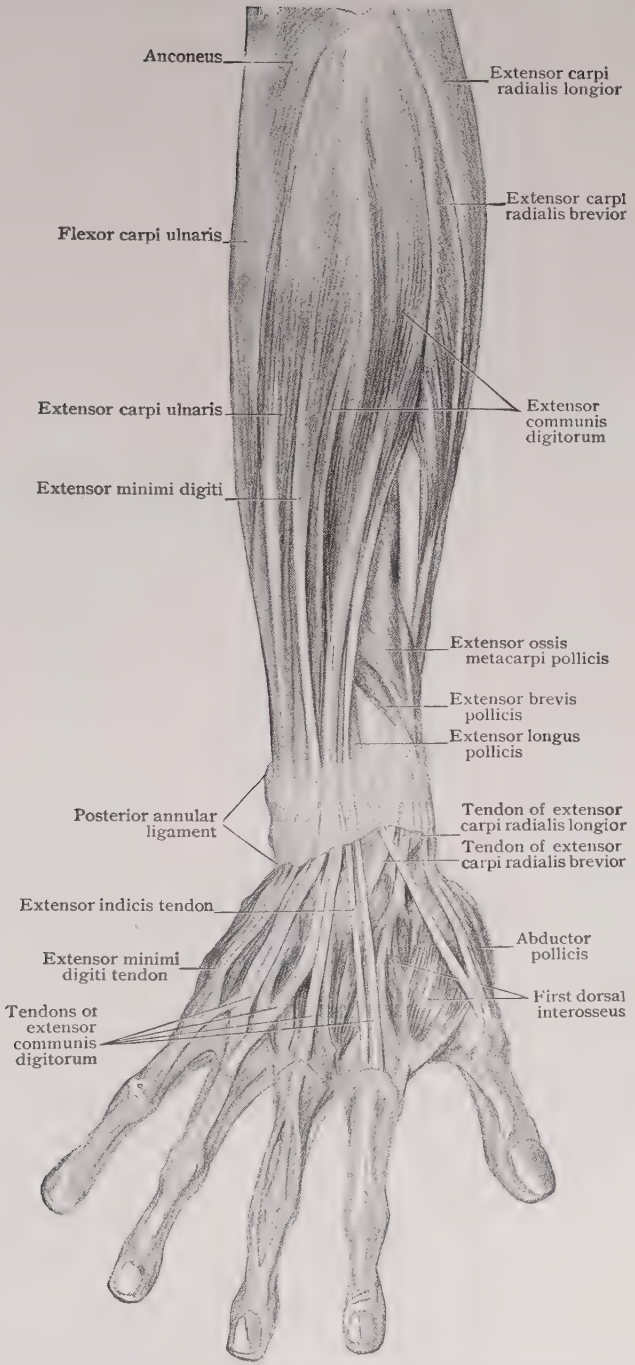


FIG. 283.—Superficial extensor muscles on the posterior surface of the forearm. (Piersol: Human Anatomy.)

Its power is much increased by the leverage it secures from being attached at the apex of the radial bow. The pronator quadratus is a flat rectangular sheet arising from the lower portion of the ulna, crossing the interosseous space and anterior surface of the radius to be inserted at its lateral border.

Supination is performed by the biceps and the supinator brevis. This latter muscle has two origins, the external condyle and orbicular ligament on the one hand, and the lateral surface of the upper part of the ulna on the other. Its fibres curve outward around the radius and are inserted chiefly on its lateral and anterior surfaces. The brachio radialis or supinator longus has a slight supinating effect when the elbow is in flexion, but functions chiefly as a flexor of the elbow. Both the short and long supinator muscles are supplied by the musculo-spiral nerve.

Vessels and Nerves.—The main vessels and nerves lie in the anterior fascial compartment of the forearm. The exception is the posterior interosseous nerve, the motor division of the musculo-spiral, which pierces the supinator brevis to gain the back of the arm and supply the extensor muscles. It is rarely damaged in cases of fracture, but is in danger of being wounded in surgical incisions over the lateral aspect of the head of the radius. The median, ulnar, and radial (sensory) nerves are practically never injured except in cases of severe compound fracture or stab wounds. The radial and ulnar vessels may be injured in the same type of accident but rarely in simple fractures.

The return of blood is almost altogether through large superficial veins lying in the fascia on the anterior aspect of the forearm and particularly the anterior aspect of the elbow. This superficial position renders compression of them by splints dangerously easy and may lead to serious circulatory disturbance if care is not employed. The brachial artery is also quite superficial as it lies in the antecubital fossa.

OPTIMUM FUNCTIONAL POSITION

When there is complete loss of the movements of rotation of the forearm, the position of greatest usefulness is fifteen degrees short of complete pronation.

From the standpoint of recovery of function, motion in the direction of pronation is more quickly recovered than in the direction of supination. This is because the greatest use of the hand is with the forearm pronated. If the forearm is immobilized in the position of supination, every effort to use the hand will tend to increase the range of motion.

I. FRACTURE OF THE SHAFT OF THE ULNA

Causation.— The ulna is fractured practically always by direct violence, often from the receipt of a blow on the upraised forearm or from a fall, the arm being struck against the edge of a step or similar object.

Fracture may occur at any level, but points of structural weakness exist in the bone just distal to the middle of the shaft and in the upper third about one inch below the coronoid, where there is a constriction intended to provide clearance for the bicipital tuberosity of the radius in movements of pronation. The fracture may be complete or incomplete and is frequently compound.

Displacement.— There is nothing constant about the displacement, this depending chiefly upon the direction of the fracturing force. Over-riding of the fragments is prevented by the splint-like action of the intact radius. There is a constant tendency in the cases with displacement to narrowing of the interosseous space due to radial deviation of the lower fragment

by the action of the pronator quadratus muscle. It uncorrected, this may later interfere with movements of the radius in rotation of the forearm. This is commonly associated with an angular deformity, the bowing being directed either anteriorly or posteriorly.

Diagnosis.— Swelling and ecchymosis at the site of injury develop quickly and arrest attention. The existence of deformity is easily

FIG. 284.—Fracture of the shaft of the ulna from direct violence. Very little displacement.

recognizable by palpation. Tenderness on pressure sharply localized over the fracture line is marked. If the fracture is complete, crepitus and abnormal mobility are present, but the diagnosis is usually clear without the necessity of eliciting them. A radiogram should be made as a matter of routine to clarify obscure features of the injury.

II. FRACTURE OF THE SHAFT OF THE ULNA ASSOCIATED WITH DISLOCATION OF THE HEAD OF THE RADIUS

Causation.—A frequent complication of fracture of the ulna in the upper third is dislocation of the head of the radius. It is caused by the temporary continuance of the original force which after fracturing the ulna comes in contact with the shaft of the radius. Under these circumstances the orbicular ligament yields more readily than the bone, with the result that the radius is dislocated instead of fractured. The dislocation may be either of the anterior or posterior variety, depending upon the direction of the force, but owing to the greater exposure of the upper portion of the ulna to violence, acting from the posterior direction, the

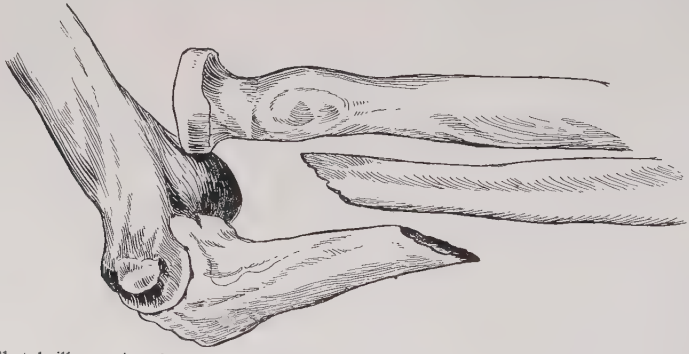


FIG. 285.—Sketch illustrating fracture of the upper third of the ulna associated with anterior luxation of the head of the radius.

forward type of displacement is by far the more frequent. The interosseous membrane remains intact and limits the amount of displacement.

Diagnosis.— The special importance of the injury lies in the frequency with which the feature of dislocation is overlooked. The safe way to avoid error is to look for dislocation of the upper end of the radius whenever fracture in the upper third of the ulna is recognized, particularly when there is considerable anterior displacement of the fragments. Swelling and tenderness can be demonstrated over the upper end of the radius, there is a hollow where the bone should be, and the head can usually be located, lying either in front or behind its normal position. Rotation of the forearm is limited and painful.

III. FRACTURE OF THE SHAFT OF THE RADIUS

Frequency.— The radius is more frequently fractured than any other bone with the possible exception of the clavicle. The great majority of such injuries involve the extreme lower end of the bone, and discussion of these is postponed until the next section, for consideration in connection with injuries of the wrist.

Level of Fracture.— Fractures involving the shaft proper occur most frequently in the lower and middle thirds. In the former region the bone is weakened by the transition from hard cortical tissue to soft spongy bone and is greatly exposed to the action of both direct and indirect

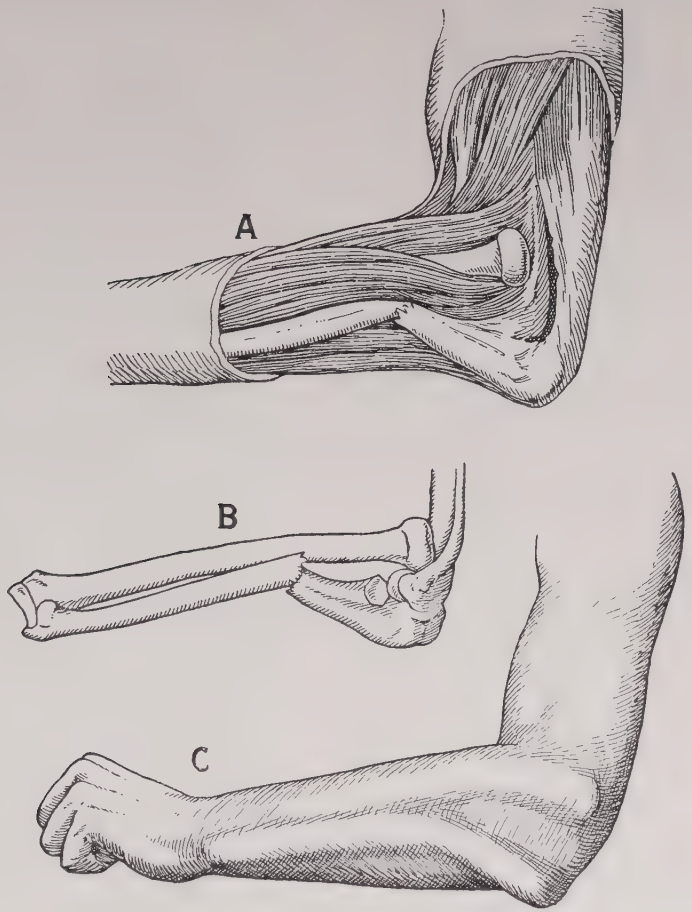


FIG. 286.—Fracture of the upper third of the ulna associated with dislocation of the head of the radius. (A) Showing displacement in relation to the muscles. Between the head of the radius and the upper end of the ulna is the anconeus muscle. (B) Condition in skeleton. (C) Deformity in patient. (Modified from Helferich.)

violence. In the middle third a point of structural weakness is produced by the junction of the outward and inward curves which form the radial convexity. The upper third is well protected from direct violence by its thick muscular covering, and indirect violence is apt to cause fracture at a lower level.

Causation.— As between direct and indirect forms of violence, the shaft of the radius is fractured by one as frequently as the other. The for-

mer usually results from a blow on the radial side of the forearm while the mechanism of indirect violence is usually a fall on the outstretched

FIG. 287.—Fracture of the radius above the insertion of the pronator radii teres muscle. Drawing to illustrate the classical type of displacement. The upper fragment is flexed and supinated while the lower fragment is pronated.

FIG. 288.—Fracture of the radius below the insertion of the pronator radii teres muscle. The upper fragment is flexed but less supinated than in the preceding figure and the lower fragment is less pronated.

hand, the force being transmitted to the radius by virtue of its direct articulation with the carpus and hand. The greenstick type of fracture is frequent in children. Fracture of the radius alone is rarely compound.

Displacement.—Displacement is common in complete fracture of the shaft of the radius, and, due to the motion permitted at the superior and inferior radio-ulnar articulations, may partake of a rotary character in addition to the usual deformity in the antero-posterior and lateral planes.

289 290

FIGS. 289 and 290.—Fracture of the lower third of the radius. Union with deformity. (Fracture Service, M. G. H.)

Muscular action is a very important factor in determining the type of displacement.

Above the Pronator Insertion.— If the fracture occurs above the insertion of the pronator radii teres, the upper fragment is flexed by the biceps and supinated by the biceps and supinator brevis (see Fig. 287). The lower fragment is rotated away from the upper one and lies in the position of semi-pronation, due to the action of the pronator teres. At the same time it is drawn toward the ulna and the interosseous space narrowed by the pronator quadratus and brachio-radialis muscles, the latter acting by pulling upwards on the radial styloid with inward tilting of the upper end of the fragment.

Below the Pronator Insertion.— If the fracture is below the insertion of the pronator radii teres this muscle acts on the upper fragment to neutralize the effect of the supinators so that while it is still flexed there is less supination (see Fig. 288). The lower fragment is also less displaced. There is the same tendency to narrowing of the interspace and obliteration of the radial bowing by the action of the pronator quadratus and brachio-radialis muscles, but there is less pronation. When the fracture is in the lower third the distal fragment usually lies posterior to the proximal fragment, simulating the displacement in Colles fracture.

Shortening.— In fracture of the radius with complete displacement there may be slight over-riding of the fragments, rarely exceeding 1 cm. The radius shortens by pulling the hand with it so that the latter is abducted (deviated radially).

Diagnosis.— In cases of complete fracture the classical signs are nearly always present. The points of special importance to be noted are the absence of rotation of the head of the radius when the forearm is pronated or supinated, the abducted position of the hand, the ascent of the radial styloid in relation to the ulnar styloid if the fragments have slipped by each other, and the demonstration of shortening by measurement from the external epicondyle of the humerus to the tip of the radial styloid.

In cases of incomplete fracture the above signs are absent, but angular deformity is usually revealed by palpation, and local tenderness on pressure is always present.

A roentgenogram should be made in all cases and is important to show the degree of bony injury, the level of the fracture and the displacement, even when unnecessary for diagnosis.

IV. FRACTURE OF BOTH BONES

Causation.— Fracture of both bones of the forearm is a common injury. It occurs chiefly as a result of direct violence, as when the arm is run over or crushed between two objects. Less frequently it is produced by indirect violence, chiefly from falls on the hand. With indirect violence the bones are apt to be fractured at different levels, while with direct violence the level is more often the same. It occurs at all ages. In children it is frequently incomplete or greenstick. As the fracture is often the result of considerable violence, it is frequently compound.

Displacement.— The displacement varies greatly in different cases and is chiefly determined by the angle from which the fracturing force acts. The fragments may be displaced in either the antero-posterior or lateral planes or rotated axially. Angular deformity chiefly occurs when the fracture is incomplete. In all cases of complete fracture there is a

tendency of the radius and ulna to be drawn towards each other, with narrowing of the interspace. This is partly due to the action of the pronator muscles, but also results from the general muscular tension.

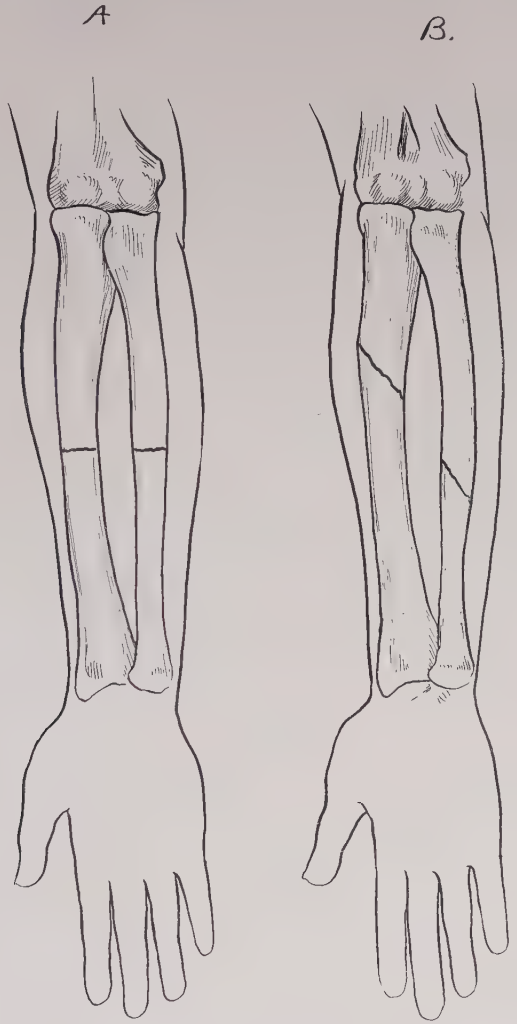


FIG. 291 (A, B).—Types of fracture of both bones of the forearm. (A) Direct violence; both bones fractured at same level. (B) Indirect violence; bones fractured at different levels.

Over-riding of the fragments is common and the natural result of the tonicity of the muscles passing from the elbow to the wrist.

Diagnosis.—The diagnosis presents no difficulties when the fracture is complete, as all of the classical signs are present. With greenstick fracture, bowing or angular deformity is obvious. The diagnosis should always be confirmed by a roentgenogram and is necessary to show the

presence or absence of comminution, the variety of the fracture, and the exact type of displacement.

TREATMENT OF FRACTURES OF THE BONES OF THE FOREARM

GENERAL CONSIDERATIONS

Fractures of the forearm are chiefly to be regarded from the standpoint of how they affect the movements of pronation and supination and the function of the fingers and wrist. Visible deformity is, of course, undesirable, but alteration in the axes of the joints is not likely to be productive of static strain as in the case of the leg. However, in the forearm, slight variation in the position of the bones is sufficient to impair considerably or even prevent completely the movements of the radius upon the ulna, resulting in diminution of the usefulness of the hand. Complete restoration of the normal alignment is, therefore, as important as in any other fracture. Narrowing of the interosseous space is particularly to be corrected because of the possibility of cross union occurring between the radius and ulna.

Fractures without Displacement.—As in the case of all fractures, the treatment varies depending upon the degree of displacement and other local considerations. Simple fractures without displacement are readily dealt with by fixation alone. Both the wrist and elbow-joints should be immobilized. Either plaster of Paris splints or the antero-posterior board splints, the latter in combination with the anterior angular aluminum splints (Figs. 293-295), may be used. The aim should be to avoid over-treatment, of which there is danger, and to prevent circulatory disturbances and joint stiffness. Massage should be begun immediately and active use of the fingers permitted from the beginning. Supported movements of the wrist and elbow may be allowed daily after the first week.

Fracture of a Single Bone with Displacement.—In cases of fracture with displacement, the difficulty of the problem varies, depending upon whether one or both bones is broken. In the former case, the matter of securing alignment is simplified because of the limiting and splinting action of the bone that remains intact. If the case is approached with a proper understanding of the factors concerned in the displacement and the dangers to be avoided in its treatment, a good result may generally be expected from the use of conservative methods alone.

Fracture of Both Bones with Displacement.—When both bones are broken and displaced, the difficulties are greatly increased. Not two, but four, fragments must be brought into alignment, and rotary displacement, in addition to deformity in the antero-posterior and lateral planes, must be corrected. The size of the bones is small and if the fracture is situated in the muscular part of the forearm, reduction presents great difficulty. Unfortunately traction methods, although valuable, cannot be depended

upon to the same degree for the correction of deformity as in fractures elsewhere, and skeletal traction in the region of the wrist is scarcely advisable. For these reasons and because of the slight risk to the patient involved by the operation itself, open reduction is more frequently resorted to than in the case of many other fractures. Such procedure is justifiable in the hands of well-equipped surgeons with meticulous technic and large experience in the operative treatment of fractures, but under other auspices is likely sooner or later to result in disaster. Closed methods of reduction are successful in a large percentage of cases and should not be abandoned in favor of open methods until after a fair trial in each case.

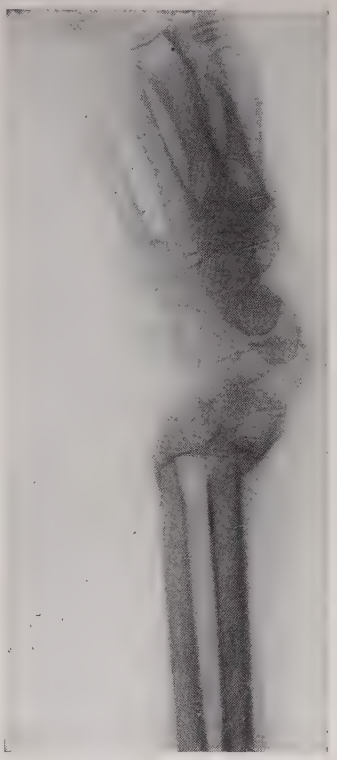
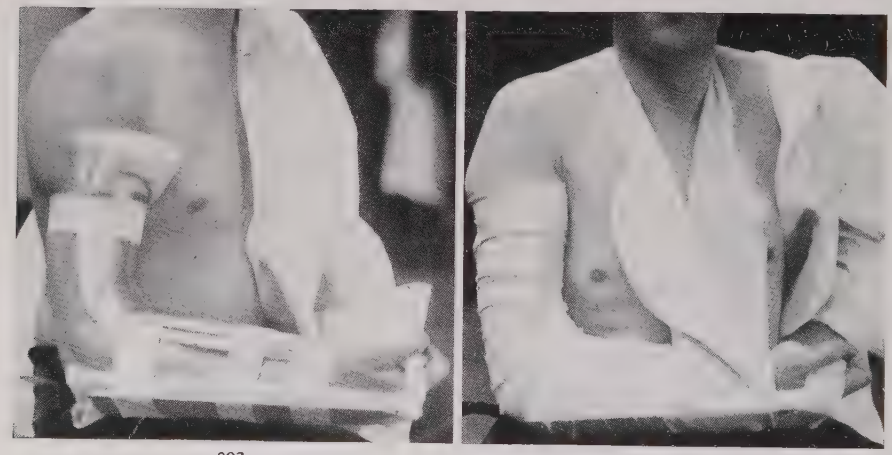


FIG. 292.—Fracture of the lower ends of both bones of the forearm. Union has occurred in deformed position. (Edinburgh Royal Infirmary.)

Reduction.—Manipulative reduction should be attempted in all cases of simple fractures with displacement which are seen shortly after injury. The time element is very important and the earlier the reduction is performed, the greater the chances of success. With the lapse of time, contraction of the muscles and other tissues adds to the difficulty of correction. The manipulation should always be performed under anæsthesia, preferably ether. Reduction is greatly facilitated when it can be done with the aid of the fluoroscope. The various steps of the procedure should be carried out with extreme gentleness to avoid adding trauma to already injured tissues. The methods to be employed are described later under the heading of the specific injuries.

The arm may be immobilized with the elbow completely extended or flexed to a right angle, depending upon which position seems to best meet the requirements of the individual case. Right angle flexion is the more comfortable and convenient position for the patient and is always indicated when the radius alone is fractured, on account of the usual flexion deformity of the upper fragment. When the ulna alone is broken or in case of fracture of both bones with displacement, the choice of position should be governed by experiment at the time of reduction. When continuous traction methods are employed, right angle flexion is the better position, as counter-traction may then be obtained from the anterior surface of the upper arm.

With respect to rotation of the forearm, the position of supination is usually best and is generally indicated except in fracture of the ulna with displacement and in certain fractures of both bones. Anatomically, this position favors correction of deformity. If the radius is fractured, rotary displacement of the lower fragment is prevented and the important radial convexity preserved. It holds the ulna and radius well separated and minimizes the danger of synostosis. It is also the optimum position for the recovery of function because the normal use of the hand is with



293 294

FIGS. 293 and 294.—Method of splinting fractures of the forearm. (293) Anterior and posterior board splints abundantly padded are applied in conjunction with an internal angular elbow splint, preferably of aluminum. (294) Dressing completed by addition of a bandage and cravat sling.

the forearm pronated, and every effort to use the hand will tend to increase the range of motion.

Fracture of the ulna is an exception to this rule, as in supination the pronator quadratus muscle is tense and the lower fragment is drawn towards the radius. The muscle is relaxed by the position of pronation, and furthermore in this position the fragments of the ulna are pushed out of the way by the radius, so that the possibility of later limitation of pronation by ulnar deformity is prevented. The bones are approximated, so that the chances of synostosis are increased, but this danger is small if immobilization is not maintained for too long a time.

Splinting.— The splinting of the fracture varies depending upon whether the plan of treatment to be followed is one of reduction and fixation or correction by continuous traction. In the former case, the apparatus must furnish complete immobilization; in the latter it must provide the means of securing traction as well. In order to obtain complete fixation, the old rule of immobilizing joints above and below the injury should be observed.

Fixation may be obtained either by the use of antero-posterior wooden splints, in combination with the anterior angular aluminum splint or by plaster of Paris.

Wooden and Anterior Angular Splints.— The wooden splints are cut from ordinary splint board and should be of length sufficient to extend from the distal palmar crease of the hand to just below the elbow, the posterior splint being slightly longer than the anterior one. The anterior splint should be cut out widely for the thenar eminence, and approximation of

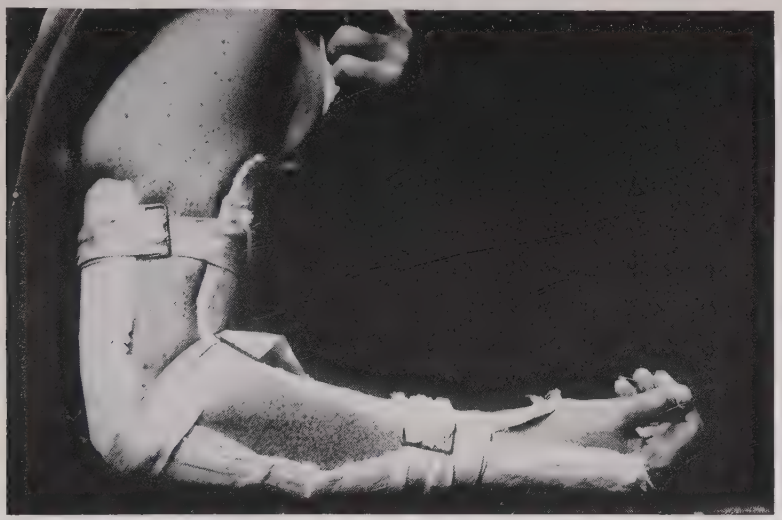


FIG. 295.—Anterior and posterior moulded plaster splints in fractures of the forearm. The splints should extend well up to the axilla and may be retained in place by adhesive strips and bandage.

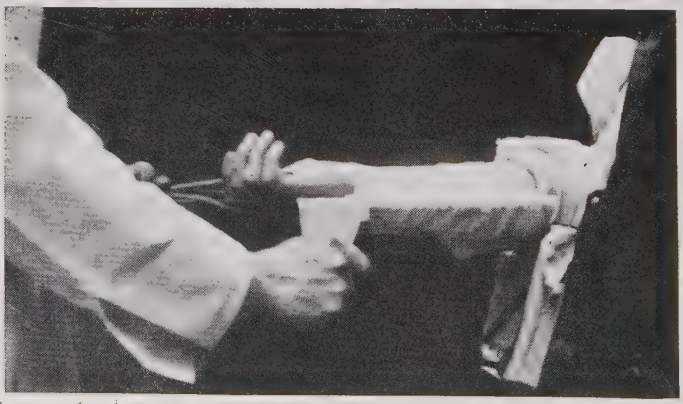
the thumb to any of the fingers should be possible (Figs. 358–364). The width of the splints should be slightly less than that of the arm. They should be voluminously padded with folded sheet cotton and fixed in place by adhesive bands with the forearm rotated into the desired position (Figs. 293, 294). The anterior angular splint, its two limbs forming a right angle, should be made of aluminum, which does not interfere with the penetration of the X-rays. The metal splint is applied with abundant padding between it and the exposed skin surface and fixed with additional strips of adhesive. The entire apparatus is then enclosed with bandage and a sling provided. The splints may be readily removed for massage or inspection of the injured part, the forearm being supported on the inferior wooden splint to prevent change in the position.

Plaster Splints.—Although the wooden and metal splints previously described provide effective fixation, the writers prefer plaster of Paris as the splinting material. This is because of its great adaptability and the necessity of reducing the number of manufactured splints that must be kept on hand, and furthermore because when properly applied it does

296

297

298



FIGS. 296, 297 and 298.—Traction in fractures of the forearm. Either the Jones humerus traction splint or the modified splint with the hinge-joint may be used. (296) Traction strips are applied to the forearm and tied to the end of the forearm piece. Additional tension is obtained by twisting the traction cords with a nail, counter-traction being obtained by a band across the front of the arm. (297) Traction on the flexed elbow is necessary to retain the splint in position. In order to hold the arm in full supination, a band of adhesive may be applied at the radial side of the wrist. (298) This is carried across under the back of the wrist to the inner side of the splint, where it is fastened.

not tend to flatten the hand and forearm, as is the case with the previous type of apparatus. Plaster may be used either in the form of a cylindrical casing or as moulded splints. In either case the arm should be abundantly padded and the splint should extend above to the axilla and below to the metacarpo-phalangeal articulation which corresponds to the distal palmar crease. The plaster should be moulded into the hand to preserve the palmar arch and should be cut out freely about the thenar eminence in order to allow apposition of the thumb to the fingers. In addition the wrist should be fixed in moderate dorsi-flexion, the position

FIG. 299.—Traction in fractures of the forearm. A traction splint may be improvised from a wire frame which is incorporated in a plaster casing, enclosing the upper arm. The traction bands are fastened as indicated to the end of the frame, tension being obtained by twisting them with a stick.

which permits maximum function of the fingers and hand. Attention to these details is particularly important in reducing disability time.

When the arm is fixed with the elbow in extension we prefer to use the solid plaster casing, as it is easy to maintain the alignment of the fragments by traction during its application. If, on the other hand, the elbow is to be fixed at right angle flexion, we use the moulded splints, as it is more difficult to support the arm in this position and there is danger of disturbing the alignment by the manipulation incident to the application of a cast. The moulded splints are made by applying thick strips of plaster bandage, of appropriate length, to the front and back of the arm, where they are secured with gauze roller bandage and allowed to harden. When the solid plaster cast is used the precaution should always be taken to split it as soon as it has hardened, in order to allow room for expansion in case of swelling.

Continuous Traction Methods.—Continuous traction methods of treatment are indicated in cases of fracture with displacement, when there is over-riding of the fragments. These are usually cases of fracture of both bones which come into the hands of the surgeon late, or in which

the method of reduction and fixation has been tried and failed. Occasionally, in recent cases, with oblique fracture lines, traction is indicated as the primary method of treatment because of the improbability of being able to retain the fragments in position by the ordinary methods of splinting.

Traction Splints.—The Jones humerus traction splint may be used for this purpose, counter-traction being secured by a sling passing

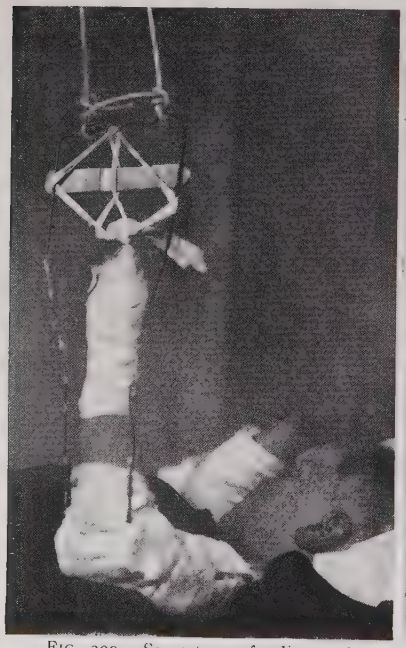


FIG. 300.—Same type of splint as shown in figure 299, showing method of suspension with the patient recumbent. In this case, traction is being obtained from the anterior and posterior surfaces of the hand as well as from the wrist. (Fracture Service, M. G. H.)

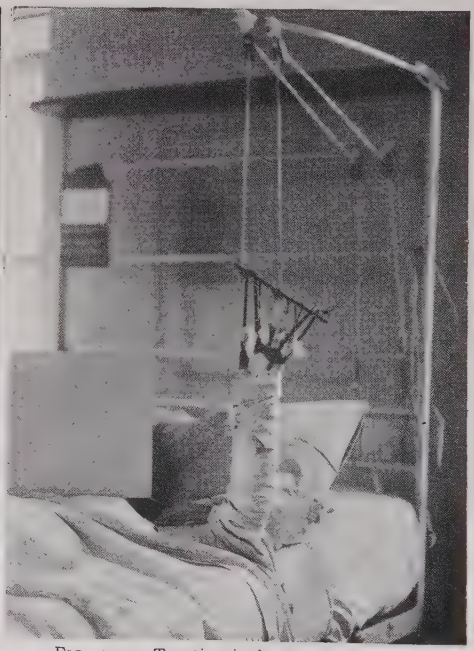
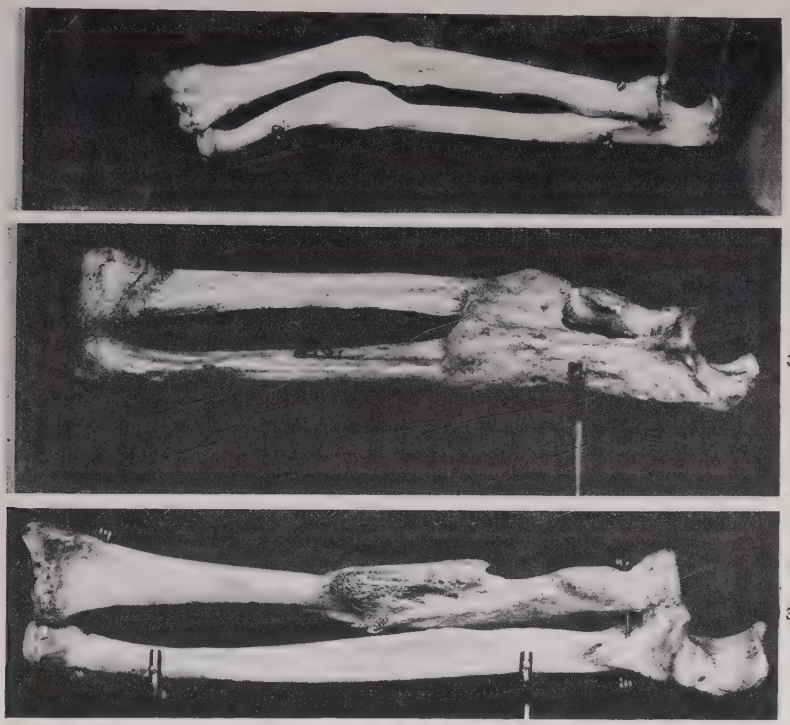


FIG. 301.—Traction in fractures of the forearm. If the fracture is near the wrist, traction must be obtained by means of a glove which is glued to the hand. This may be connected to the overhead suspension frame as shown. The purpose of the small wooden cross-piece to which the cords from the glove are fixed is to allow change in the position of the hand in the direction of abduction or adduction as indicated by the needs of the fracture. (Fracture Service, M. G. H.)

across the front of the upper arm and fixed to the vertical bars of the splint (Figs. 296-298). The splint is retained in position by means of a traction strap passing across the forearm in front of the elbow or if this is inadvisable by the use of adhesive traction strips fixed to the upper arm. The forearm is supported by flannel slings pinned to the splint. An equally satisfactory, if not better, splint may be improvised from plaster of Paris and heavy steel wire (Fig. 299). The wire is bent to form a frame enclosing the forearm and extending five to six inches beyond the finger tips. A plaster cast is applied to the arm above the elbow, over a thick layer of padding, and in this the wire frame, with its ends bent upward at a right angle, is incorporated by additional turns of plaster bandage.

Application of Traction.— Traction is secured either in the ordinary manner with adhesive strips or by the use of a glove glued to the hand, to the front and back of which are sewed webbing tapes. The tapes are tied



FIGS. 302, 303 and 304.—Fracture of both bones of the forearm. Anatomical specimens illustrating various deformities following fracture of both bones. (302) Angular deformity. (303) Synostosis between radius and ulna. (304) Note rotary displacement of radius; the upper fragment occupying a position of full supination while the lower fragment is in midpronation. (Warren Anatomical Museum.)

to the end of the wire frame and tension obtained by twisting them on the principle of the Spanish windlass (Fig. 300). More effective still is the recumbent method of treatment, in which extension is secured by means of a weight and overhead pulley (Fig. 301).

Further Measures.— The further treatment of the case, after reduction or application of traction, depends in large measure upon the correction obtained, as shown by the second set of roentgenograms, which should be invariably obtained at this stage. If deformity is still present, but of only minor degree, it is possible to improve the position by the use of pads of felt or cotton placed over the fragments in such a manner that when the splints are reapplied additional pressure is exerted to bring them into alignment. If this procedure is not feasible, a second manipulation may be tried, after a short preliminary period of traction, or it may be necessary to resort to open reduction.

DANGERS

1. Circulatory interference is very apt to occur in fractures of the forearm and very commonly results in ischæmic paralysis or even gangrene. Prevention of these tragic complications lies altogether in attention and careful supervision of the after-care. Every plaster cast must

FIG. 305.—Roentgenogram of old fracture of the ulna associated with anterior luxation of the head of the radius. The fracture had been plated with subsequent infection and osteomyelitis. Note the sequestrum and the excessive callus. Also the unreduced displacement of the upper end of the radius. (Fracture Service, M. G. H.)

be split as soon as it has hardened and preferably on two sides. Not only the plaster but the cotton padding underneath should be cut so that the two halves of the cast are entirely free. The bandage or adhesive strips used to fasten the splints must not be applied too tightly.

The patient should be seen within twenty-four hours after the application of the splints and must be given explicit directions to look, himself, for circulatory disturbances in the hand. If there is swelling or blueness of the skin or difficulty in moving the fingers, he should be instructed to

report it at once to the surgeon. Pain, while a valuable symptom of excessive splint pressure, is not an infallible one and may be absent with approaching ischæmia.

2. Narrowing of the interosseous space, with danger of synostosis, may result from the too tight application of a roller bandage or plaster cast which presses the bones together.

3. Interference with the function of the fingers and hand is common after fractures of the forearm. It is due to the associated injury to muscles and tendons and the subsequent binding down of these structures in scar tissue. Many a person has recovered from a forearm fracture with complete anatomic restoration of the bones but with a hand that is functionally useless on this account. Much care must be taken to prevent the splints from interfering with motion of the fingers and thumb. The patient must be encouraged to move them voluntarily from the very start. Even a sling should be dispensed with after the first few days and the patient urged to use the fingers in the performance of light tasks. Early massage and exercise of the immobilized joints, under the surgeon's supervision, are important aids in reducing the length of disability.

4. The functional results of mal-union are bad. If approximation of the fragments is not secured by closed methods, open reduction is indicated. The decision as to the necessity of employing the latter method should be reached within ten days in most cases, as the results are much more successful when the operation is performed early, rather than late. Delayed union results in a small number of cases, even when the ends of the bones are in close approximation. Such cases should be given the benefit of prolonged fixation before classifying them as cases of non-union requiring operative treatment.

TREATMENT IN RELATION TO SPECIAL FRACTURES OF THE FOREARM

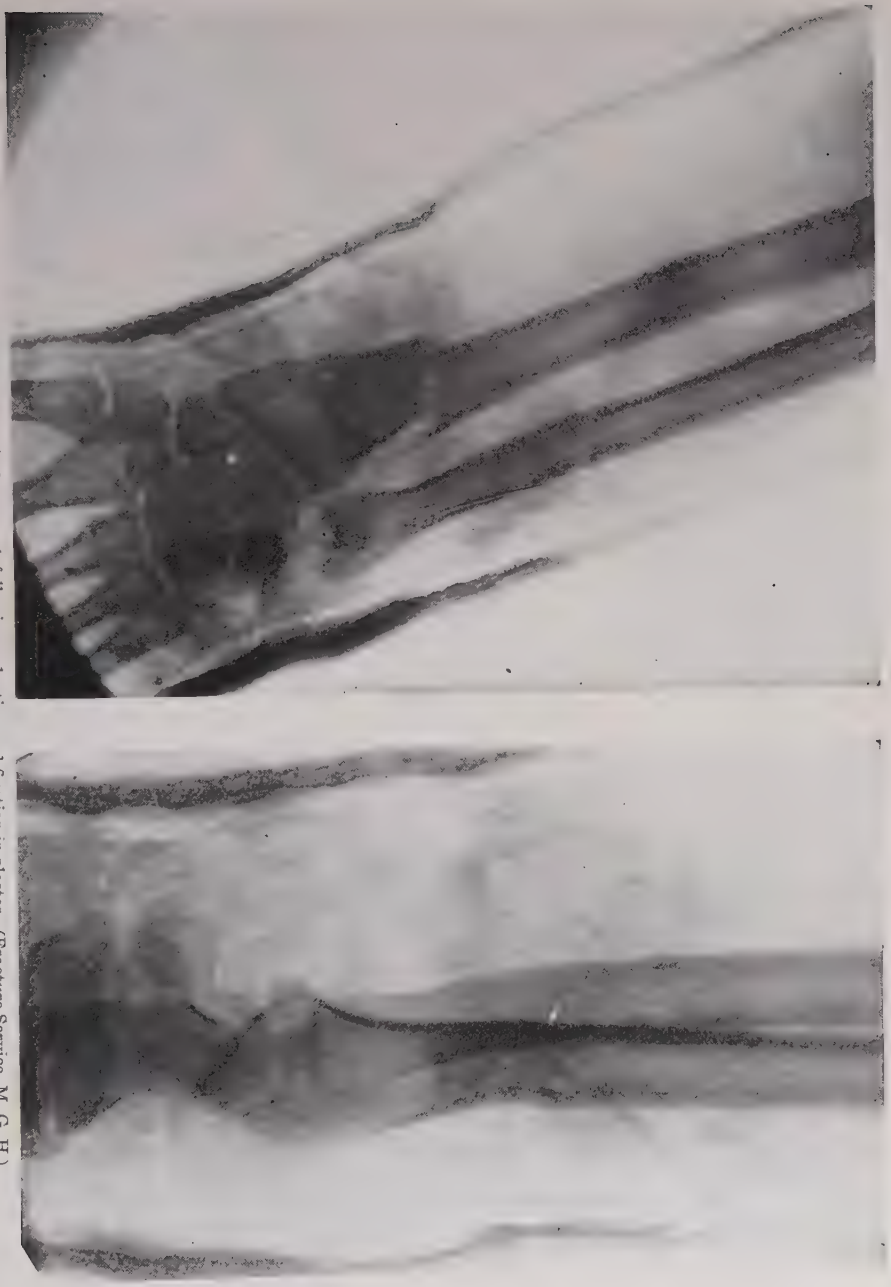
I. FRACTURE OF THE SHAFT OF THE ULNA

Reduction.—Manipulative reduction is practically always indicated for the correction of deformity. If there is considerable displacement of the bones toward the radius, the reduction should be performed with the forearm completely pronated and this position should be maintained when the splints are applied (see p. 220). If the displacement is only slight, the position of midpronation is sufficient to allow correction and is better from the functional standpoint. The elbow should usually be fixed in right-angle flexion, except in the case of posterior bowing, when the position of complete extension may be used. In the latter position, the upper fragment is fixed and force applied to the lower end of the forearm acts more effectively on the seat of deformity.

After-treatment.—Fixation apparatus alone is required (v. p. 231), traction being unnecessary. The arm should be redressed every other day during the first week, the anterior splint being removed while the posterior splint is retained for support. Light massage may be performed

FIG. 306.—Fracture of the lower end of the radius. (Fracture Service, M. G. H.)

at these times and the skin bathed and powdered. Daily massage may be employed after the first week and supported active movements of the elbow and wrist after two weeks. Union is usually complete in four to five weeks. The splints should then be removed and the arm protected by a sling for another week. Light use should be allowed at the end of four to six weeks and full use in one to two weeks later.



FIGS. 307 and 308.—Same fracture as in figure 306, following reduction and fixation in plaster. (Fracture Service, M. G. H.)

Prognosis.—Functional recovery is usually excellent. Because of the superficial position of the ulna, slight cosmetic deformity due to callus is common. Angulation, unless completely corrected, is apt to result in a visible prominence. With time, this is rounded off and becomes of little importance.

Complications.—Malalignment sufficient to require operative interference is rare. When internal fixation is required, it may be obtained by slotting the fragments with the motor saw and driving in a small key of beef bone. Exposure, in case of operation, is obtained by an incision directly over the posterior surface of the ulna. Non-union is uncommon in fracture of the ulna alone. When it does occur it must be treated operatively with freshening of the bone ends and the application of small osteoperiosteal grafts. It should be noted, however, that non-union in the lower third is not necessarily incompatible with good function.

II. FRACTURE OF THE ULNA WITH DISLOCATION OF THE HEAD OF THE RADIUS

The methods of reduction and fixation vary, depending upon the type of displacement, whether forward or backward. In the usual case with anterior dislocation, reduction may be accomplished by traction on the forearm, combined with local pressure on the radial head. The elbow should then be flexed acutely, the forearm supinated, and fixation obtained by means of a broad, posterior, moulded plaster of Paris splint (Fig. 237). In this position, the radius is retained in position by counter-pressure from the lower end of the humerus, and the ulna, if well reduced, shows little tendency to deformity. In any case, complete replacement of the radius is more important from the standpoint of future function than restoration of ulnar alignment.

In the rare cases, with the posterior variety of displacement, reduction is obtained by traction on the forearm with hyperextension of the elbow and local pressure on the head of the radius. The bones are retained in position by means of a plaster casing extending from the metacarpo-phalangeal articulation to the axilla, holding the elbow in the position of extension.

Massage should be employed early, supported movements of the elbow performed by the surgeon at the end of two weeks, and supervised active movements at the end of three weeks. The splints may be discontinued at the end of four or five weeks, and light use permitted shortly afterwards. The recovery of motion is apt to be slow and there may be permanent impairment.

309

310

FIGS. 309 and 310.—Refracture of the radius, following an old injury. (309) Before reduction. (310) Following reduction. (Fracture Service, M. G. H.)

III. FRACTURE OF THE SHAFT OF THE RADIUS

Treatment should be begun by manipulative correction of the deformity. While exerting traction on the wrist with counter-traction by an assistant on the arm, the elbow is flexed to ninety degrees and the fore-

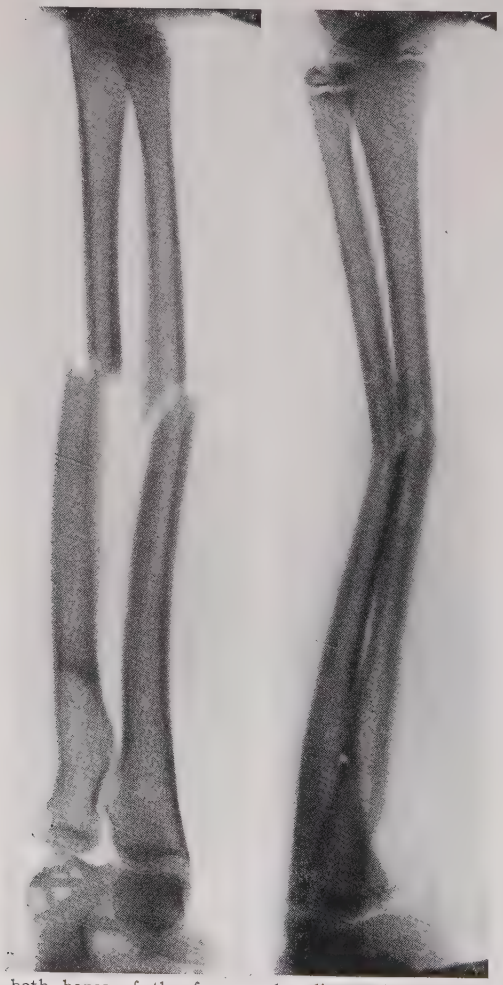


FIG. 311.—Fracture of both bones of the forearm by direct violence before reduction. (Fracture Service, M. G. H.)

arm forcibly supinated. The hand is pulled over into the position of adduction (ulnar deviation), while with the fingers of the other hand the operator pushes the fragments into alignment. Traction is maintained while the splints are applied. Either antero-posterior wooden splints with the right angle aluminum splint or anterior and posterior moulded plaster splints may be used (v. p. 231).

In cases where over-riding of the fragments cannot be corrected in this manner, a traction splint should be used. The traction strips should be applied to the radial side of the forearm and hand and should be tied to the end of the splint in such a manner as to hold the hand adducted,

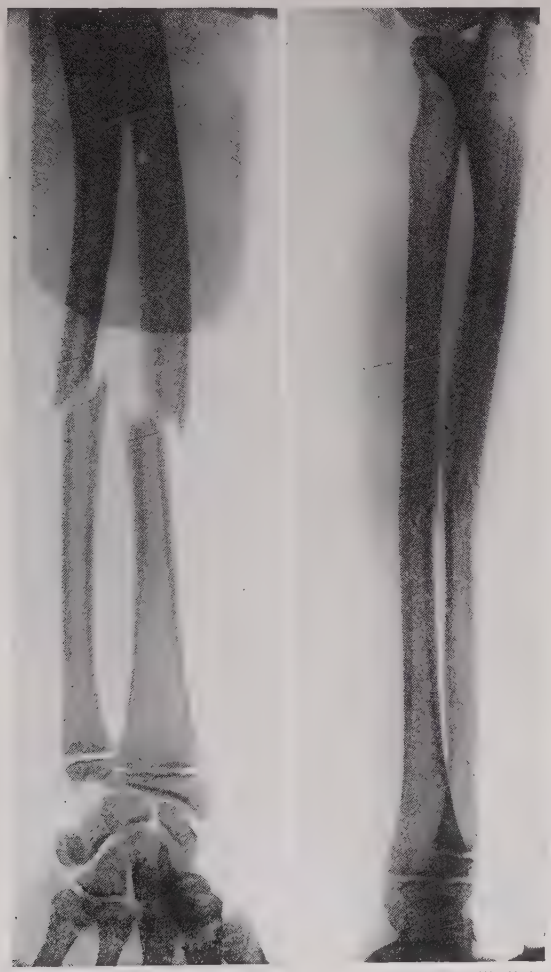


FIG. 312.—Same fracture as figure 311, following reduction. There is still slight inward displacement of the lower fragment of the radius, but the alignment in the lateral view is good. Position good enough to let alone. (Fracture Service, M. G. H.)

tension being obtained by a "twister" (Fig. 299). If after a week of traction, displacement still exists to any considerable degree, open reduction is indicated.

Fixation in splints should be maintained for about four weeks. Massage may be started at the end of one week, active movement with the arm supported by the surgeon at the end of two weeks, and supervised

active motion at the end of three weeks. After the removal of the splints a sling should be worn for a week, but light use permitted. Full use may be allowed generally at the end of six weeks.

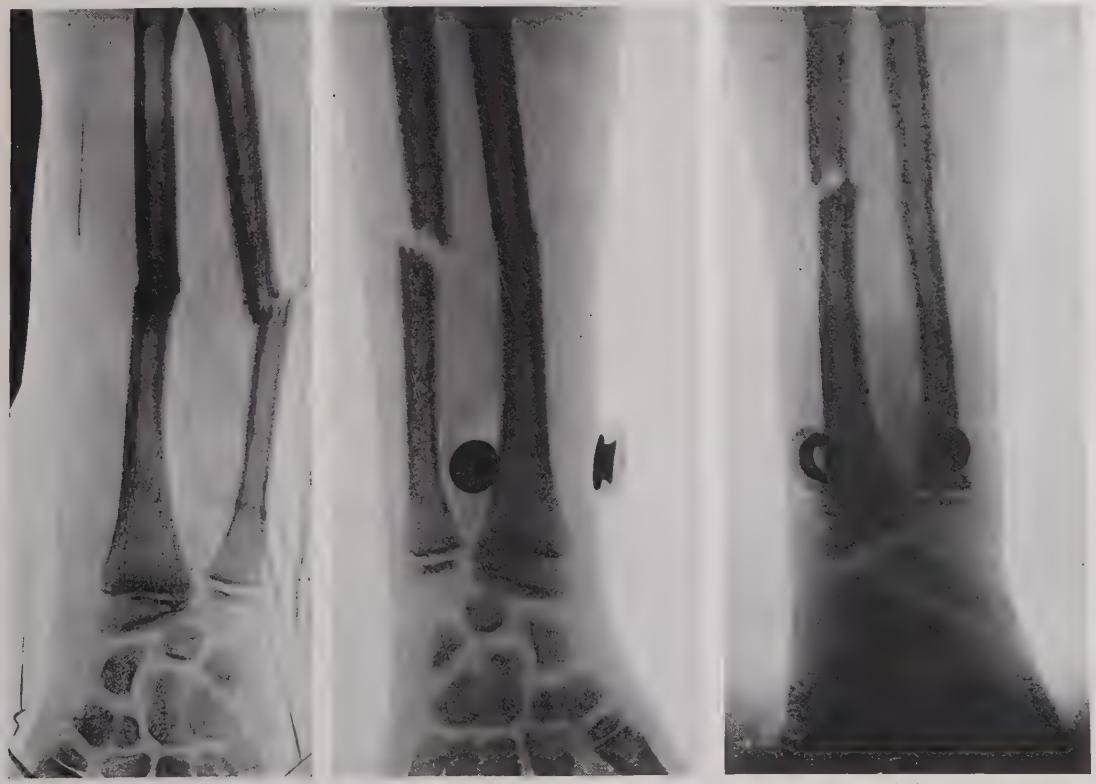
Prognosis.— Disability is rare if the treatment is properly conducted, and is directly proportionate to the degree of uncorrected displacement. It consists chiefly in limitation of rotation. Improvement in function occurs over a long period.

Complications.— Non-union is not infrequent and demands operative treatment. Caution is necessary in determining the presence or absence of union. It is easy to mistake rotary motion of the radius for true movement between the fragments. When fixation of the bones is not required, thin osteo-periosteal grafts produce union more certainly than the large grafts. When fixation is required an inlay graft will be needed. In fresh cases, when obstinate displacement necessitates operative reduction, fixation may be obtained by slotting the ends of the fragments with the motor saw and driving in a thin sliver of beef bone. The operative approach to the radius is best made in the cleft between the two radial extensors of the wrist and the extensor communis digitorum. This corresponds to a line connecting the external epicondyle of the humerus with the radial dorsal tubercle. In the upper third, this incision leads down on the supinator brevis, which must be lifted up off the radius and retracted proximally to avoid injuring the posterior interosseous nerve, which runs in its substance. If additional exposure in this region is required, the muscle may be partially divided close to its insertion.

IV. FRACTURE OF BOTH BONES

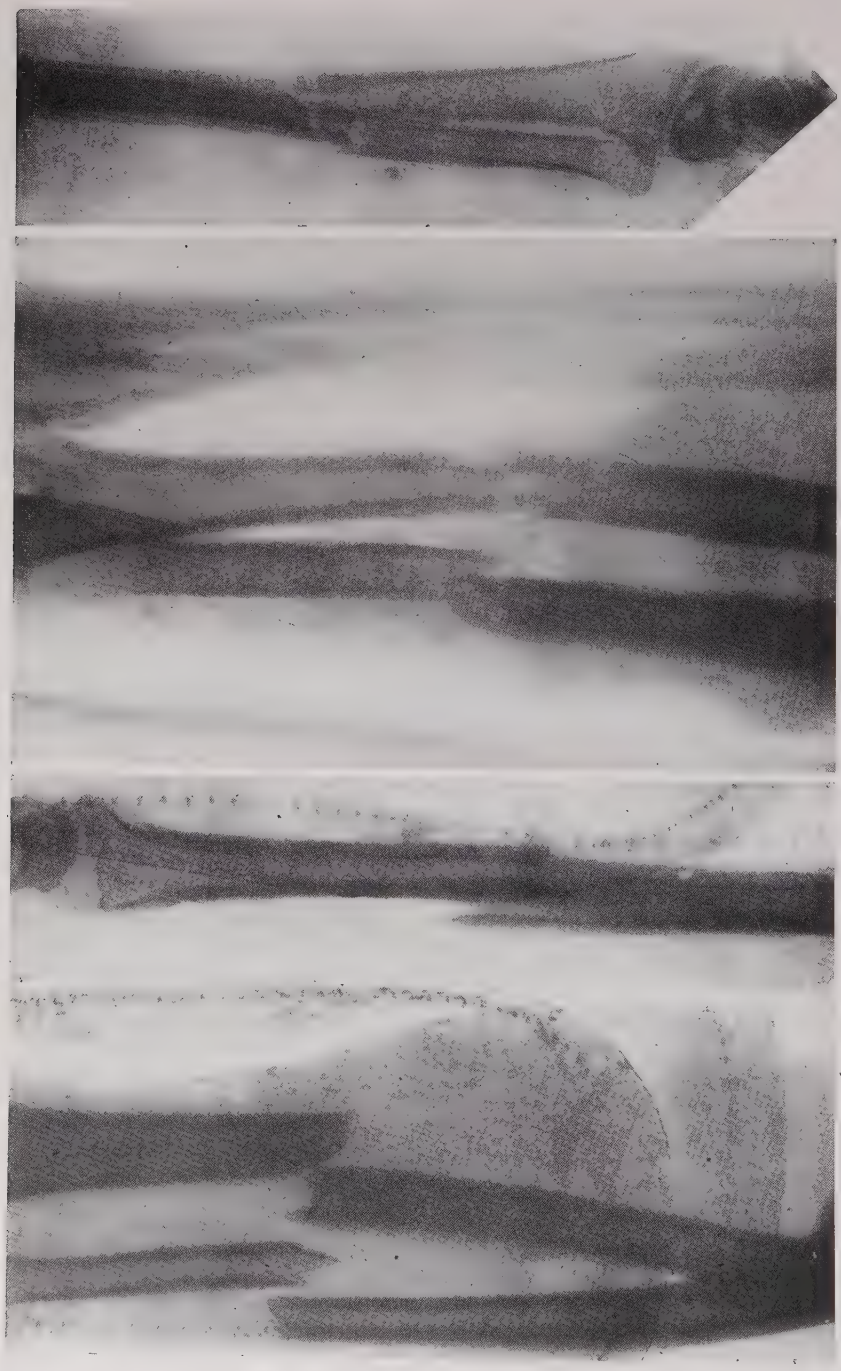
Manipulative reduction, preferably under the fluoroscope, should be attempted in nearly all cases of fracture with displacement which are seen shortly after injury. This is an emergency procedure because the chances of a successful reduction diminish considerably with every hour elapsed. Ether anæsthesia is necessary.

Reduction and Fixation.— The manipulation consists chiefly of traction and counter-traction on the arm, with local manipulation of the bones and of the forearm, until the distal fragments correspond in position with the proximal ones. It is in this latter step of the procedure that previous X-ray examination, or better still, fluoroscopic control, is invaluable. In general, the best alignment is secured by the position of complete supination, but whether this position or that of mid-pronation is selected should be governed chiefly by the position of the proximal fragments. Approximation is usually favored by fixing the arm with the elbow completely extended, as in this position the upper fragments are locked at the elbow and thus provide a fixed point for manipulation of the distal fragments. Also, it is easier to maintain align-



313 314 315

FIGS. 313, 314 and 315.—Fracture of both bones of the forearm treated by overhead traction. (Fig. 313) Original deformity. (Fig. 314) Same case after the application of overhead traction by means of a glove glued to the hand. Note the space showing between the ulnar fragments and the slight overlapping of the fragments of the radius. (Fig. 315) Same case after modification of the line of pull with the extension force now falling chiefly on the radial side. Note the separation of the radial fragments. Position satisfactory. (Fracture Service, M. G. H.)



316 317 318

FIGS. 316, 317 and 318.—(316) Fracture of both bones of the forearm with complete displacement; ten days old when seen. (317 and 318) Same fracture following open reduction. (Fracture Service, M. G. H.)

ment during the application of the retentive apparatus in this position than that of right-angle flexion. Following reduction, the arm is immobilized in a carefully applied plaster casing.

Traction.— When the reduction and fixation method of treatment is inadvisable (see p. 233) or when it has been tried and proved unsuccessful, the continuous traction method is indicated, and either of the traction splints previously described (page 234) may be employed. The first effort is to overcome shortening, and when full length has been obtained, to correct displacement by appropriate rotation of the distal fragments, the forearm being fixed in the desired position by a strip of adhesive plaster fastened to the skin and the side bar of the splint (Figs. 296-298). Pads may be adjusted to exert corrective pressure on individual fragments when necessary. By varying the position of the hand, either in the direction of abduction or adduction, encroachment by one of the distal fragments upon the interosseous space may be prevented. When these methods fail to obtain alignment, open reduction is indicated.

After-treatment.—Massage should be begun at the end of one week, exposure being obtained by removing half of the plaster casing, the arm being supported in the other half during the treatments. At the end of two weeks the arm may be lifted from the plaster daily for supported active movements of the elbow and wrist. At the end of five to seven weeks a sling may be used, depending upon the state of union. Use may be permitted at the end of seven or eight weeks. However, union is frequently delayed, and in such cases prolonged immobilization is necessary. Active use is to be encouraged in such cases, but protection should also be provided. An apparatus of moulded leather answers well for the purpose. Laced leather cuffs are made for the forearm and upper arm and these are connected by jointed steels at the elbow.

Greenstick Fracture.— Special mention should be made of the greenstick fractures of both bones so common in children. The deformity here is an angular one, and full correction can be obtained only by converting the fracture into a complete one by manipulation. Over-correction must be obtained. This procedure entails the danger of causing actual displacement of the fragments, but if done gently, this risk is small. Immobilization is obtained with plaster. Union occurs rapidly and is complete usually in three to four weeks.

Prognosis.— Fracture of both bones is one of the most difficult of all fractures to treat. Malalignment, with resulting impairment of function, is common. The only means of prevention is careful control of position by repeated roentgenograms and early resort to open reduction when correction by other methods is unsuccessful.

Functional disability of the hand can be prevented by attention to details of splinting, in order to secure optimum positions of the wrist

319

320

FIGS. 319 and 320.—(319) Fracture of both bones of the forearm in a child, several weeks after injury. Considerable deformity of radius, and union well advanced; necessitated open reduction. (320) Same fracture following open reduction. (Fracture Service, M. G. H.)

and hand and complete freedom of the fingers and thumb. Early massage and passive and active motion are invaluable. From the end of the first week the hand should be used for the performance of simple tasks requiring the use of the fingers.

Complications.—Refracture, in children, is common because of their constant activity and exposure to trauma. To prevent this, the forearm should be protected by means of a short plaster cuff extending from the wrist to the elbow or by coaptation splints for a considerable time after union seems perfectly solid.

Delayed union and non-union are frequent and require operative treatment when prolonged immobilization has failed of result. In these conditions and in cases of malalignment requiring open reduction, the operative approach and the procedures used are the same as already outlined for the individual bones, two incisions being necessary.

COMPOUND FRACTURES OF THE FOREARM

Compound fractures of the forearm result most frequently from severe crushing injuries. Generally, both bones are fractured and there is extensive damage to the soft parts as well. When the circulation of the distal portion of the arm is impaired, amputation is necessitated, but otherwise the wound treatment should follow that outlined in the section on compound fractures.

Traction methods of splinting should be employed in order to provide adequate exposure of the wound and to permit change of dressings without disturbance of alignment. The Jones humerus traction splint may be used for this purpose, and in the early stage of treatment the patient should be recumbent and the splint suspended to an overhead frame. If the wound is near the wrist it will be necessary to use the glued glove for traction purposes. Extension may also be secured by direct overhead suspension (Fig. 301).

CHAPTER IX

INJURIES OF THE WRIST AND HAND

I. FRACTURES OF THE LOWER END OF THE RADIUS

1. Hyperextension Fractures
   a. Colles's Fracture
   b. Epiphyseal Separation
   c. Oblique Fracture of the Outer Articular Border
   d. Posterior Marginal Fracture
2. Flexion Fractures
   a. Smith's Fracture (Colles's Fracture Reversed)
   b. Anterior Marginal Fracture

II. INJURIES OF THE WRIST-JOINT

1. Dislocation of Inferior Radio-ulnar Joint
2. Dislocation of the Radio-carpal Joint
3. Carpal Injuries
   a. Fractures of the Scaphoid
   b. Dislocation of the Semilunar
   c. Other Fractures and Dislocations of the Carpus
4. Carpo-metacarpal Dislocations
5. Compound Injuries in the Region of the Wrist

III. INJURIES OF THE METACARPALS AND FINGERS

1. Fracture of the Metacarpal Bones
   a. Bennett's Fracture
   b. Fracture of the Metacarpal Shaft
2. Dislocation of the Metacarpo-phalangeal Joints
   a. Dorsal Luxation of the Proximal Phalanx of the Thumb
3. Interphalangeal Dislocations
4. Fracture of the Phalanges
5. Baseball Finger
6. Compound Injuries of the Fingers and Thumb

IV. THE TREATMENT OF STIFF HANDS

ANATOMICAL CONSIDERATIONS

The Wrist-joint.—The wrist-joint is formed by the distal portions of the radius and ulna, the carpal bones, and the bases of the metacarpals. It comprises five separate and distinct synovial cavities; the inferior radio-ulnar joint, the radio-carpal joint, the intercarpal and carpo-metacarpal joints, which intercommunicate, the separate carpo-metacarpal joint of the thumb, and the special articulation for the pisiform.

The Inferior Radio-ulnar Joint.—The inferior radio-ulnar joint is formed by the articulation of the distal end of the radius with the head of the ulna. The discus articularis or triangular cartilage constitutes an important anatomical feature, being interposed between the head of the ulna and the proximal row of the carpus. It is a thick, fibro-

cartilaginous plate, triangular in outline, attached by its apex to the root of the ulnar styloid and by its base to the lower border of the mesial surface of the radius. It serves to separate the synovial cavities of the inferior radio-ulnar and radio-carpal articulations and also plays an important part in retaining the head of the ulna in approximation with the radius. Considerable support is given the joint by the pronator quadratus muscle.

The synovial cavity of the joint is "L"-shaped, the lower limb of the cavity extending horizontally between the head of the ulna and the discus articularis, while the upper

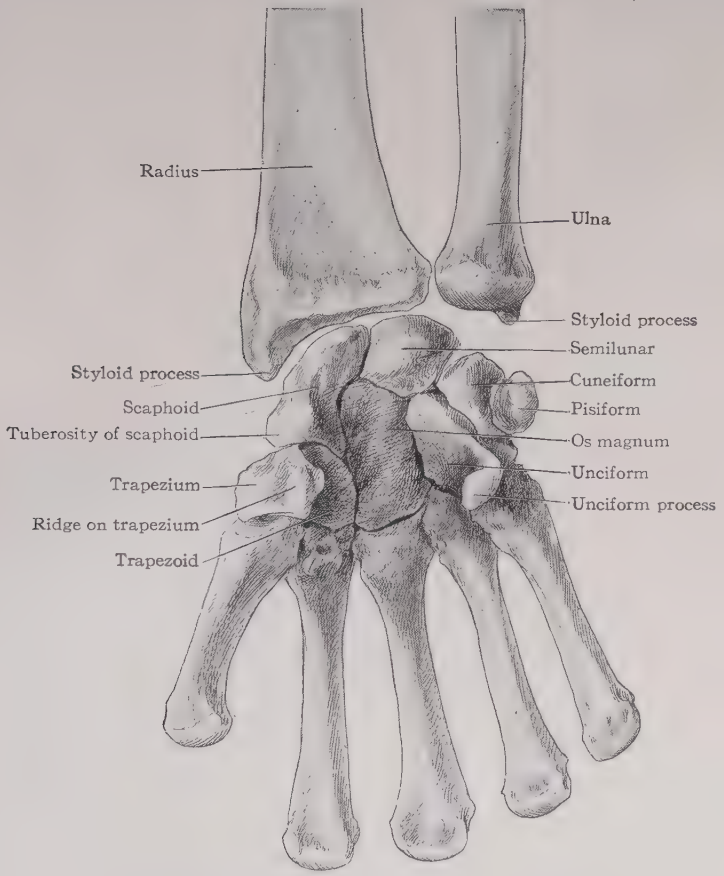


FIG. 321.—Anterior view of the lower ends of the radius and ulna, carpal bones, and metacarpals. (Davis: Applied Anatomy.)

limb extends proximally between the radius and ulna beyond the line of the respective epiphyseal attachments. On account of this latter relationship the joint cavity is necessarily implicated in epiphyseal separations. Other anatomical features of surgical interest are the shallowness of the joint cavity and the laxity of the capsular ligament. In dislocations of the head of the ulna these predispose to recurrence of the dislocation unless, following reduction, the forearm is kept at rest for a sufficient period to insure strong healing of the torn ligaments.

Movements.—The movements of pronation and supination of the forearm take place conjointly at the superior and inferior radio-ulnar articulations, but while the motion at the proximal joint is rotary in character, at the distal joint it consists of a swinging circular movement of the radius about the ulna, with the centre of motion at the ulnar styloid. In injuries involving the inferior radio-ulnar articulation, care should

be taken to preserve this movement. For purposes of immobilization the position of full supination is the one which best preserves what is the hardest part of the motion to retain, namely, the last few degrees of supination. On the other hand, should loss of motion be the likely outcome, for example, after an infected compound fracture or severe fracture dislocation, the optimum position for ankylosis is one fifteen degrees short of complete pronation.

Radio-carpal Articulation.—The radio-carpal or wrist-joint proper is formed by the articulation of the radius and discus articularis with the bones forming the proximal

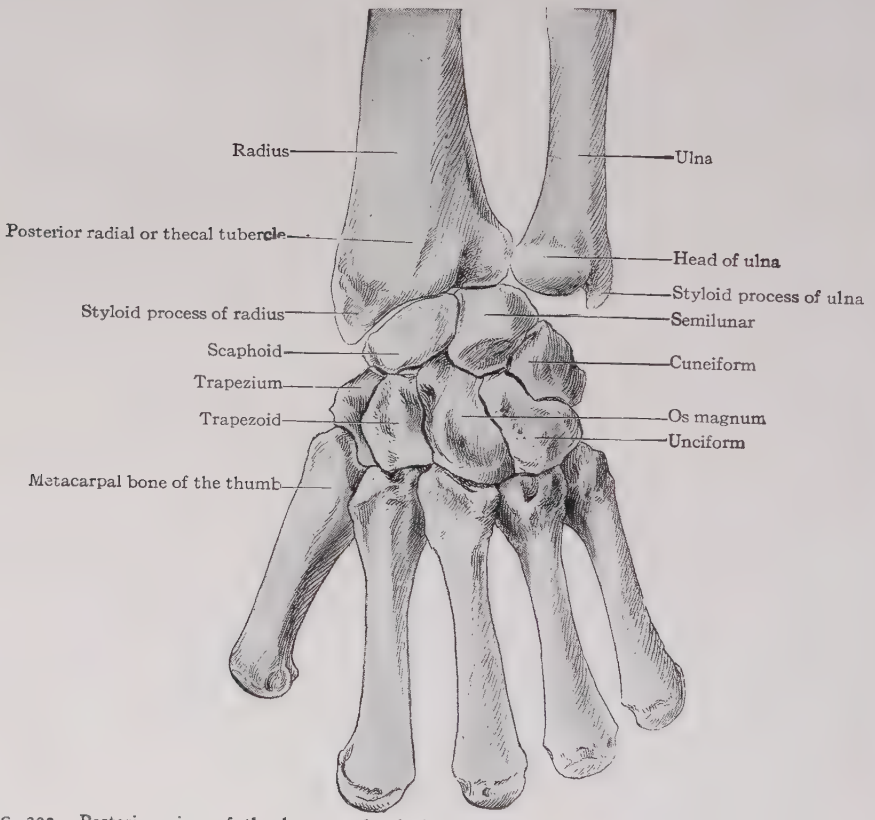


FIG. 322.—Posterior view of the lower ends of the radius and ulna, carpal bones, and metacarpals. (Davis: Applied Anatomy.)

row of the carpus, the scaphoid, semilunar and cuneiform. The proximal articular surface is oval in outline and much elongated in its lateral diameter. The surface is concave in both antero-posterior and lateral directions for the reception of the carpus, a configuration which contributes considerably to the flexibility and stability of the wrist. With the hand held in the axis of the forearm, the radius is in contact chiefly with the scaphoid, while the inner or ulnar portion of the bone and the discus articularis are in contact with the semilunar. The cuneiform enters into the articulation only when the hand is adducted or flexed ulnawards. In the latter position the carpus glides radially, the cuneiform comes in contact with the discus articularis, and the scaphoid, which has greater individual mobility than any other of the carpal bones, moves out in part from beneath the radial styloid to lie against the radial collateral ligament in the anatomic snuff-box.

Intracarpal Joint.—The intracarpal joint is constituted by the articulation of the first with the second row of the carpal bones. The joint line is irregular and undulating, the unciform and os magnum forming a high convexity in the proximal direction while the proximal surfaces of the trapezium and trapezoid lie more distally and form a concavity for the reception of the convex distal facet of the scaphoid. Obviously the arrangement of the joint is not one which permits movement in the lateral direction. The distal row of carpal bones is only incompletely united by interosseous ligaments so that the articulation between the first and second rows and that between the distal

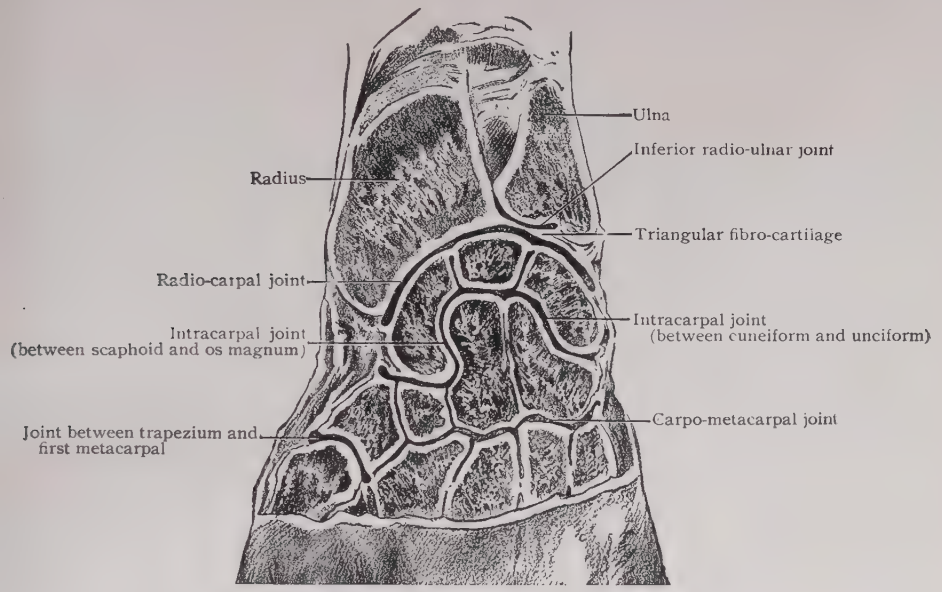


FIG. 323.—Longitudinal section through the carpus to show the arrangement of the synovial sacs. (Piersol: Human Anatomy.)

row and the four outer metacarpals communicate with each other and together form a common carpal joint.

Carpo-metacarpal Joints.—The bases of the four metacarpals of the fingers articulate by means of lateral facets and are united just distal to these by strong interosseous ligaments. They are mortised into the distal row of carpal bones in an irregular fashion which assures stability but permits only the slightest power of movement. The carpo-metacarpal joint of the thumb is a separate joint by itself and the close apposition of its saddle-shaped facets is essential for proper function of that digit.

The Carpal Ligaments.—The general plan of the ligamentous arrangement of all these joints is that of a capsular ligament common to all and extending from the articular borders of the radius and ulna to the bases of the metacarpal bones. Between these attachments it effects connections with the first and second rows of the carpal bones. It is reinforced by accessory bands, the lateral ligaments being the most important. The external lateral ligament extends from the radial styloid to the base of the first metacarpal and in addition is attached to the tubercle of the scaphoid and the trapezium. The internal lateral ligament passes from the ulnar styloid to effect similar connections with the cuneiform, unciform and base of the fifth metacarpal. On the strength of these ligaments the stability of the wrist-joint chiefly depends.

Interosseous Ligaments.—A system of dorsal, volar and interosseous ligaments unites the individual bones. The dorsal and volar ligaments are simply accentuations or local thickenings of the general capsular envelope previously mentioned. Two interosseous ligaments composed of strong, fibrous tissue strands unite the bones of the proxi-

mal row and being situated at the proximal ends of the bones, form part of the joint surface of the radio-carpal joint. They close the space between the scaphoid, semilunar and cuneiform and separate the synovial cavities of the radio-carpal and intercarpal joints. Three interosseous ligaments unite the bones of the distal row but none pass

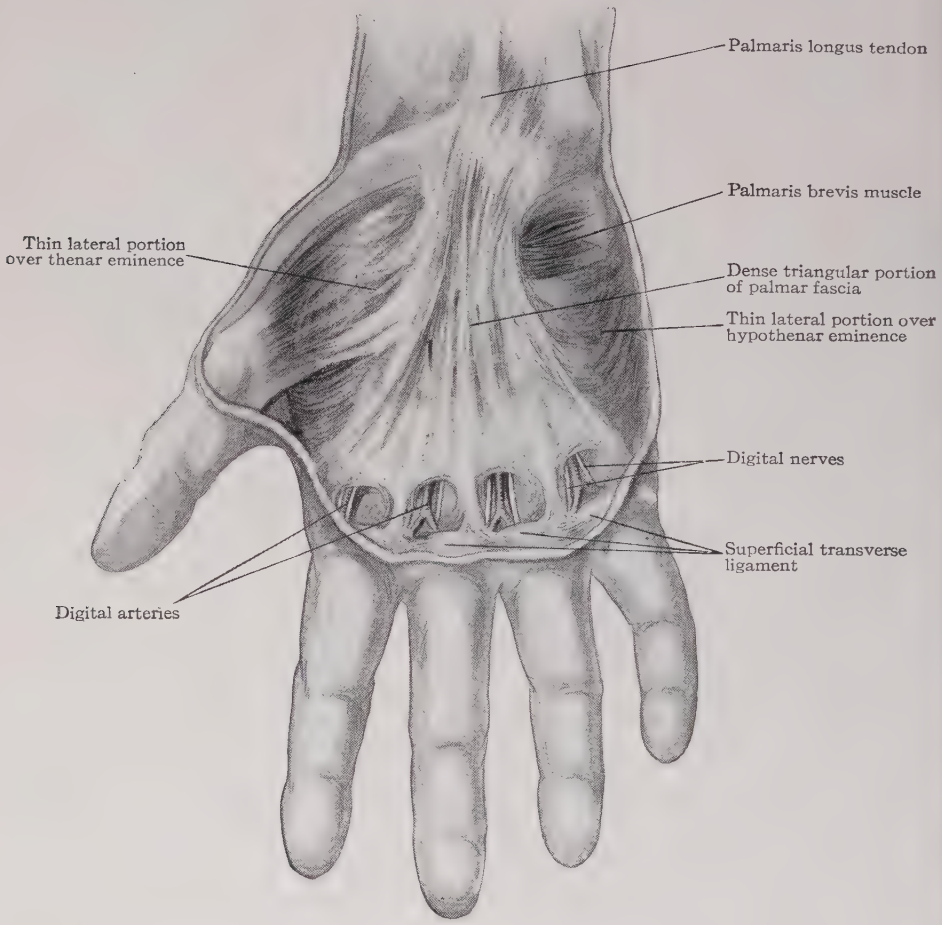


FIG. 324.— The palmar fascia. (Davis: Applied Anatomy.)

between the two rows so that a small amount of motion in the antero-posterior plane is possible in the transverse part of the intercarpal joint.

Mechanism of Carpal Injuries.—Todd[1] suggests that the carpal bones function as buffers to distribute and dissipate the effects of forces transmitted upward from the hand to the forearm. When one considers the lesser structural resistance of the carpal bones in comparison with that of the adjacent bones of the hand and forearm it is easy to understand how carpal injuries occur. That they are not produced more frequently is due to the number and small size of the bones and the multiplicity of the joints which provide extreme flexibility and elasticity.

Motion of the Carpal Joints.—The movements of the wrist consist of flexion (palmar flexion), extension (dorsi-flexion), adduction (ulnar flexion), abduction (radial

[1] A. H. Todd. *Brit. Journ. of Surgery*, July, 1921, p. 7.

flexion). Although the major parts of these movements occur at the radio-carpal joint the other carpal joints contribute small amounts of motion which help to swell the sum total. As far as movement of the individual bones is concerned the scaphoid possesses the greatest potentiality of motion. (Todd.) Anatomically there is present a radio-carpal pocket which permits different positions of the scaphoid in ulnar and radial deviation of the hand, but in addition Mozier has shown that the bone tilts antero-posteriorly during the movement of abduction (radial flexion) so that the tuberosity comes

325 326

FIGS. 325 and 326.—Roentgenograms showing the osseous development of the normal hand. (325) Age of two years. (326) Age of three years.

forward. The capacity for individual motion possessed by the scaphoid is important from the standpoint of roentgenology because of the varied appearance which the bone presents depending upon the position of the hand at the time the roentgenogram is made.

The bones of the proximal carpal row do not receive any tendinous attachments so that their rôle is a passive one comparable to that of the semilunar cartilages of the knee. Flexion of the wrist is limited by the tension of the dorsal ligaments and forcible hyperflexion is likely to result either in tearing of the ligament, dorsal dislocation of one of the bones of the proximal row (in hyperflexion the latter row passes backward while the distal row passes forward) or in fracture of the scaphoid. Lateral dislocation of the wrist from either extreme abduction or adduction is strongly opposed by the lateral ligaments. The styloid process of the radius provides additional resistance to radial dislocation and because its prominence is greater than that of the ulnar styloid abduction of the hand is more limited than adduction.

Motion at the Carpo-metacarpal Joints.—Motion at the carpo-metacarpal joints is almost absent in the case of the index and middle metacarpals and is limited to slight movement in the antero-posterior plane in the case of the fourth and fifth metacarpals. Much greater mobility is exhibited by the carpo-metacarpal joint of the thumb, motion being permitted in the lateral as well as in the antero-posterior plane for the purpose of securing apposition of the digits.

327

328

329

FIGS. 327, 328 and 329.—Roentgenograms showing the osseous development of the normal hand. (327) Age of four years. (328) Age of ten years. (329) Age of twelve years.

Ossification.—The bony centres for the distal epiphyses of the radius and ulna appear in the third and sixth years respectively and unite about the twenty-fifth year. The attachments of the capsule of the wrist-joint are well below the epiphyseal lines so that in epiphyseal separations the radio-carpal joint is not necessarily injured.

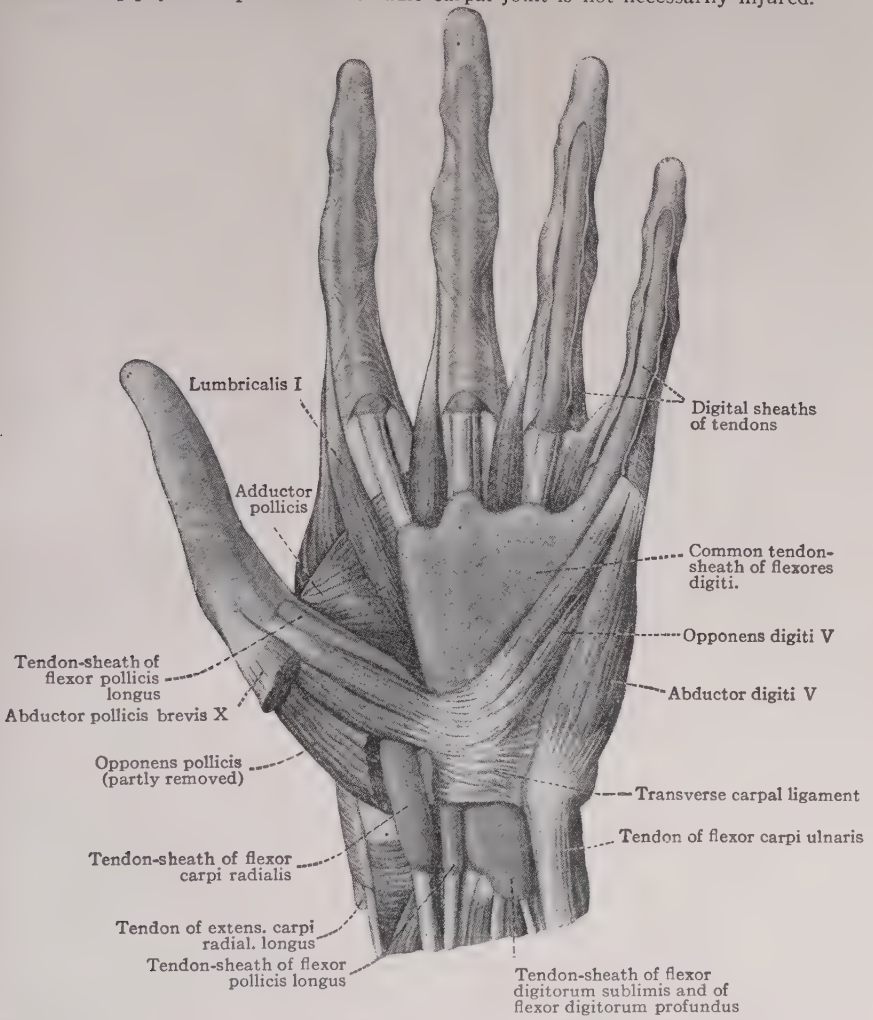


FIG. 330.—Anterior view of superficial dissection of the hand, showing the muscles of the thumb and fingers and the arrangement of the tendon-sheaths. (Sabotta: Human Anatomy.)

All the bones of the hand and wrist develop from preformed cartilaginous elements. Those of the carpus ossify in the following order: os magnum (1st year), unciform (2d year), cuneiform (3d year), semilunar (5th year), trapezium and scaphoid (6th year), trapezoid (7th year) and pisiform (10th year).

Anatomical Variation in the Carpus.—In lower vertebrate forms the typical carpus is made up of two rows of bones, the proximal one containing three elements, radial, ulnar and intermediate, and the distal one five "carpalia," each supporting a metacarpal; between the two rows is placed an "os centrale." In the human carpus the os radiale is represented by the scaphoid, the intermedium by the semilunar, and the os ulnare

by the cuneiform; the pisiform is usually regarded as a sesamoid. The five carpalia are represented by the (1) trapezium, (2) trapezoid, (3) os magnum and (4-5) unciform. The os centrale either disappears or joins the scaphoid. These developmental relations are of importance in explaining the frequent finding of anomalous or additional carpal bones in roentgenograms of the region. The presence of such bones is due to the persistence of centres that normally disappear or the separate development of

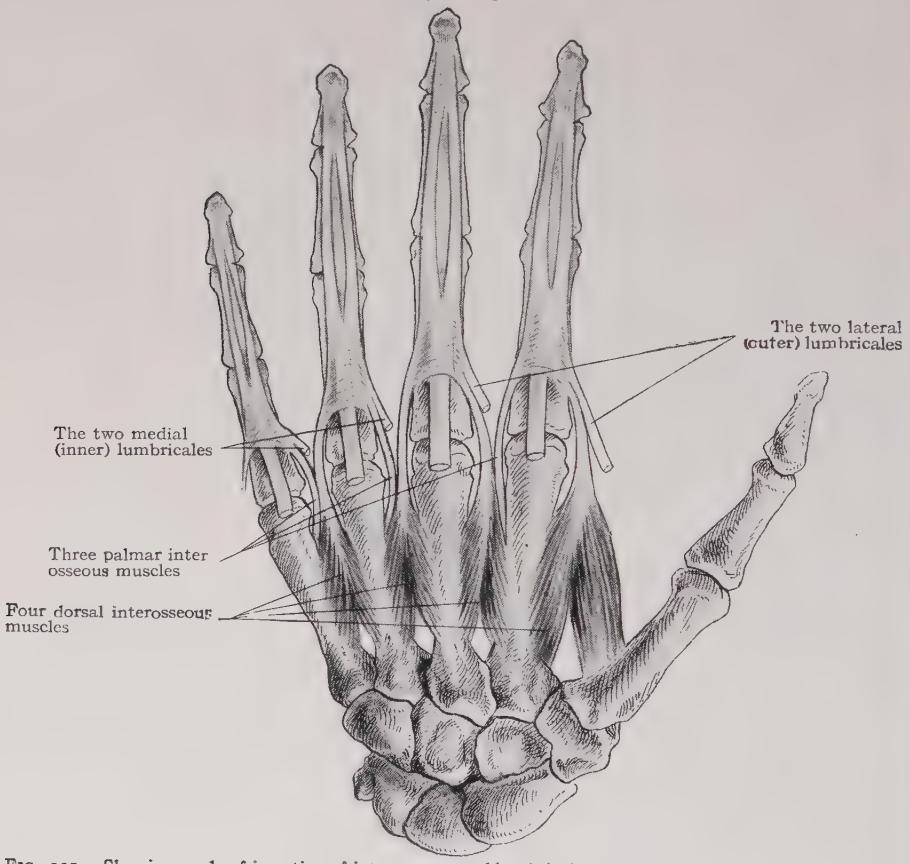


FIG. 331.—Showing mode of insertion of interosseous and lumbricale muscles. (Davis: Applied Anatomy.)

others that ordinarily fuse. Thus the scaphoid, unciform or os magnum may be bipartite, the styloid process of the third metacarpal may be separate and occasionally an os centrale is present.

THE ARCHES OF THE HAND

Functional Importance of the Palmar Arches.—The anatomy of the hand is somewhat intricate and although it well repays study, lack of space forbids its detailed consideration here. However, one feature of the anatomy, the arched arrangement of the hand, requires particular mention both because of its importance in relation to good function and to the fact that it has not received proper emphasis in the past. Indeed the preservation of the arches of the hand is just as important for the conservation of function as it is in the case of the foot. Flattening of the hand commonly occurs as the result of improper splinting, and those having to treat hand and wrist injuries should be familiar with the simple rules necessary to avoid this complication. Obliteration of the

palmar arches may well follow a comparatively trivial injury and may lead to considerable prolongation of the disability period or even to permanent disablement.

The Longitudinal Arch.—Although the hollow of the hand in reality consists of a series of arches, one merging into another, it is more convenient in describing them to speak of one longitudinal and two transverse arches. The longitudinal arch is constituted by the slight dorsal convexity of the carpus and metacarpus in the longitudinal axis and the position of slight flexion adopted by the digits when at rest. It is delineated more clearly by the disposition of the palmar fascia in forming the hollow of the palm. Flattening of the longitudinal arch may result from fracture of the metacarpals or prolonged application of an improperly cut or padded flat splint. It is attended by a flattening of the knuckles and hyperextension of the fingers at the metacarpo-phalangeal joints. Apparently the lumbricales and interossei muscles which flex the metacarpo-phalangeal joints and oppose the action of the common extensor tendons, act at a disadvantage when the arch is obliterated, and allow the opposing muscles to hyperextend the digits.

The Proximal Transverse Arch.—The transverse arches are two in number, proximal and distal; both are well marked. The proximal transverse arch has its anatomic basis in the curved shape and arrangement of the carpal bones, which form a short,

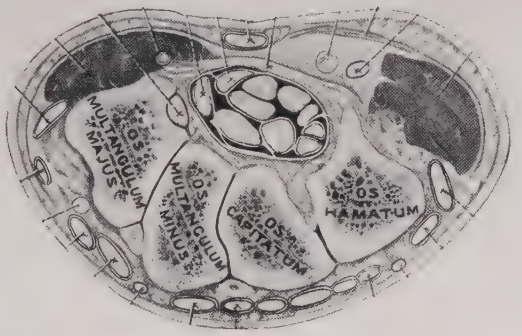


FIG. 332.—Cross section through the distal row of the carpal bones, showing transverse arch and flexor tendons enclosed in the annular ligament. (Cunningham: Manual of Practical Anatomy.)

deep trough for the passage of the flexor tendons into the palm. The bony arch is converted into a tunnel by the attachment of the anterior annular ligament to its piers (see Fig. 332). The latter is a strong band attached to the pisiform and the hook of the unciform on the ulnar side and to the tubercle of the scaphoid and ridge of the trapezium on the radial side. If this arch becomes flattened then the support which its walls afford the flexor tendons, before they spread out fan-like to operate the digits, is lost and is reflected in proportionate weakening of the power to grasp. Also, due to slight rotary change in the axis of the metacarpals, there is inability to converge the finger tips by flexion to a nodal point for opposition with the thumb.

The Distal Transverse Arch.—The distal transverse arch is the extension of the proximal transverse arch and is formed by the heads of the metacarpals and their ligaments. This arch is broader than the proximal one and more gently curved. It is accentuated when the hand is functioning, by virtue of the slight flexion of the fourth and fifth metacarpals, which comes into action when the hand is clenched. Flattening of this arch plays a part in the production of the hyperextension deformity of the knuckles previously mentioned.

Flexibility of the Arches.—The arches of the hand are flexible rather than rigid structures and their curves may be increased or diminished by muscular action. Indeed, in active use of the hand they are constantly changing according to the needs of function. The muscles of the thenar and hypothenar eminences play the predominant rôle in controlling these movements, which are called forth chiefly by opposition of the fingers and thumb. The use of improper splints which flatten the hand causes pressure injury and atrophy of these muscles, and without them function is impossible.

The Thumb and the Palmar Arches.—Opposition of the fingers as in grasping is the most important function of the thumb and the movement which this involves takes place chiefly at the carpo-metacarpal joint. The stability of this joint depends upon the close approximation of its saddle-shaped articular surfaces. The radial half of the proximal transverse arch, as represented by the scaphoid and trapezium, serves as a foundation to support the thumb. When this arch becomes weakened and relaxed

FIG. 333.—Characteristic deformity in flat hand.

the scaphoid rotates outward, opening a space between it and the os magnum, the trapezium loses its support, and the strength and mobility of the thumb are reduced. Roentgenological study of such cases shows that the axis of the first metacarpal is altered in relation to its opposing articular surface and that there is beginning subluxation of the basal joint of the thumb.

Prevention and Treatment of Flat Hand.—Lastly it is important to emphasize that many of the disabilities which follow hand and wrist injuries are the result of

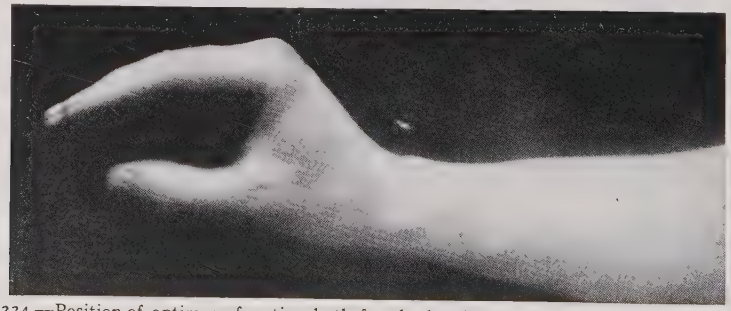


FIG. 334.—Position of optimum function both for the hand and wrist. The wrist is dorsi-flexed, the fingers partially flexed, and the thumb in the position of opposition: that is, lying in the direct prolongation of the axis of the radius, beneath and in the same plane as the index finger. This is the so-called position of grasp.

failure to treat them with due regard to the structural arrangement or the requirements of good function. Flattening of the hand may be produced by change in contour of the bones due to malunion, or may result from the use of improper splints which press injuriously upon the thenar and hypothenar eminences. Plaster splints are usually the best for the preservation of the arches, as they can be moulded into the hollow of the hand. When flat, wooden splints are used they should be cut out widely in the region of the thumb, permit complete flexion of the fingers and be properly padded to preserve the palmar arches. Flattening due to muscular weakness and general relaxation

should be treated by contrast bathing, active exercises, and the use of a simple wrist strap (see Fig. 373), encircling the hand at the level of the carpo-metacarpal joints, thus restoring the proximal transverse arch.

OPTIMUM FUNCTIONAL POSITIONS

Function of the hand is markedly affected by the position of the wrist, as is evidenced by the fact that practically always when the hand and fingers are used the wrist is extended (dorsi-flexed). Flexion of the wrist is a position of weakness and renders impossible the closing of the fist and strong use of the hand. The optimum functional position for ankylosis is one of thirty degrees extension (dorsi-flexion). This is also the position of election for general purposes of fixation to shorten disability-time and preserve the

FIG. 335.—Normal relation of the styloid processes.

function of the hand. In all cases the splints should be applied with a view to preserving the normal arches of the hand.

When immobilization of the fingers and thumb is required the optimum position is with the palmar arches well supported, the fingers slightly flexed and the thumb in full abduction and opposition, the so-called "position of grasp" (Fig. 334). Indeed with the thumb in this position, even in case of ankylosis of the carpo-metacarpal joint, an excellent degree of function is assured, as the fingers can be opposed to the thumb and grasping movements are possible. The first interosseous space must be kept open to its fullest possible limit.

LANDMARKS IN THE REGION OF THE HAND AND WRIST

The styloid processes of the radius and ulna are the two most important landmarks in the region of the wrist and alteration of their normal relationship is of great diagnostic significance. Both may be readily palpated at the lateral borders of the wrist, the tip of the radial styloid occupying the floor of the anatomic snuff-box and lying 1.25 cm. distal to that of the ulnar styloid. The head of the ulna forms the prominence on the back of the wrist when the hand is pronated. The styloid of the ulna lies below and in front of the head and marks the upper limit of the wrist-joint proper. The relegation of a point of local tenderness as to whether it lies above or below the tip of the radial styloid is of importance in distinguishing between injuries of the radius and carpus.

Between the radial styloid and the base of the first metacarpal are situated the tuberosity of the scaphoid and the ridge of the trapezium. Pressure applied over the proximal half of the anatomic snuff-box elicits tenderness from compression of

the radial nerve, which lies in an exposed position over the base of the scaphoid. This may be misleading as to the possibility of a fracture of the scaphoid, but, in the uninjured wrist, if the pressure is maintained, pressure analgesia soon develops, while, in the case of fracture, the pain becomes increasingly severe. On the ulnar side of the wrist, the pisiform and hook of the unciform are palpable. The scaphoid and semilunar can be felt on the dorsum of the wrist and also the posterior lip of the articular surface of the radius. The dorsal radial tubercle is the prominence on the back of the lower end of the radius lying in the line of the cleft between the index and middle fingers. On the dorsum of the hand the projection of the os magnum and the base of the third metacarpal are noticeable. Into the latter is inserted the tendon of the extensor carpi radialis brevis. On the ulnar side the insertions of the tendons of the flexor carpi ulnaris and extensor carpi ulnaris into the pisiform and base of the fifth metacarpal, respectively, may be recognized.

I. FRACTURES OF THE LOWER END OF THE RADIUS

Classification.—In 1814 Colles,[1] of Dublin, described for the first time as a clinical entity a fracture of the lower cancellated extremity of the radius, transverse in type and situated about four cm. above the articular margin, which resulted from a fall on the outstretched hand. The distal fragment was displaced upward and backward. Thus originated the term Colles's Fracture, which has since come to be applied indiscriminately to practically all fractures of the lower end of the radius. Such use of the term is unfortunate, because included within this group are fractures of varied etiology, type and displacement. From the standpoint of diagnosis, prognosis and treatment, it is important to separate these different injuries, and while classification on a minute etiological basis is scarcely yet possible, the following represents a method of subdivision of clinical value. The term "Colles's Fracture" has become firmly established and deserves to be retained, but should be limited to fractures involving the entire thickness of the bone produced by a fall or blow received on the palm of the extended (dorsi-flexed) and pronated hand.

I. FRACTURES FROM FALL OR BLOW ON PALM OF HAND WITH WRIST EXTENDED (DORSI-FLEXED)

A. COLLES'S FRACTURE

Transverse, fissured or comminuted fractures involving the whole thickness of the lower cancellated extremity of the radius.

a. Fractures without displacement.

b. Fractures with posterior displacement of lower fragment.

c. Fractures with or without posterior displacement but complicated by fracture of ulnar styloid or dislocation of the head of the ulna.

B. EPIPHYSEAL SEPARATION

C. FRACTURES OF LATERAL ARTICULAR BORDER AND RADIAL STYLOID

D. FRACTURES OF POSTERIOR ARTICULAR MARGIN

[1] Colles, *Edinburgh Med. Journ.*, 1814, Vol. X, p. 182.

II. FRACTURES FROM FALL OR BLOW ON DORSUM OF HAND WITH FLEXION OF THE WRIST

A. SMITH'S FRACTURE (COLLES'S FRACTURE REVERSED)

Transverse or comminuted fracture involving the whole thickness of the lower extremity of the radius with or without anterior displacement of the lower fragment.

B. FRACTURES OF THE ANTERIOR ARTICULAR MARGIN

C. EPIPHYSEAL SEPARATIONS

I. FRACTURES FROM FALL OR BLOW ON PALM OF HAND WITH WRIST EXTENDED

A. COLLES'S FRACTURE

(Transverse, fissured or comminuted fracture involving the whole thickness of the lower extremity of the radius, with or without posterior displacement of the posterior fragment, produced by a fall or blow on the extended (dorsi-flexed) palm.)

Incidence.—This type of fracture is by far the most common injury of the lower end of the radius, fractures of which stand second in order of frequency to fractures of the clavicle. It may occur at any age, but is especially common in elderly persons, whose bones are weakened by rarefactive changes, and in vigorous adults, whose occupation or activity exposes them particularly to trauma.

Mode of Production.—The most common mode of production is a fall on the outstretched and pronated hand. A second frequent method of causation is by the back firing of an automobile engine which is being cranked by hand, the so-called "chauffeur's fracture." The exact mechanism of injury is not entirely clear and several factors are undoubtedly involved. Attempts to produce the fracture experimentally have not given constant results under different conditions. Clinical data do not yield all the information desired, because of the difficulty of obtaining an accurate history from the patient, and of the fact that it is not only necessary to analyze the position of the shoulder, elbow, forearm and wrist at the moment of injury, but also to know the angle at which the limb strikes the ground and the part that receives the force.

Mechanism of Injury.— To hyperextend the hand when falling is an instinctive reflex action and this feature is constantly present in the fractures produced by falls. Pronation also appears to be of importance in determining the type of fracture and is usually present in combination with hyperextension. "If at the moment of impact the angle between the axis of the forearm and the ground is less than sixty degrees, the line representing the direction of the force passes upwards in front of the axis of the forearm. The whole shock is, therefore, borne by the lower end of the radius, which is broken off, and the force being continued, the lower fragment is driven backwards." (Cheyne.)

In the opinion of Pilcher,[2] the fracture may be produced by indirect violence due to forcible dorsi-flexion of the wrist. In the latter movement a cross-breaking strain is brought to bear upon the lower end of the radius by force exerted through the anterior ligament of the wrist-joint. He points out that this ligament is attached one-quarter inch above

FIG. 336

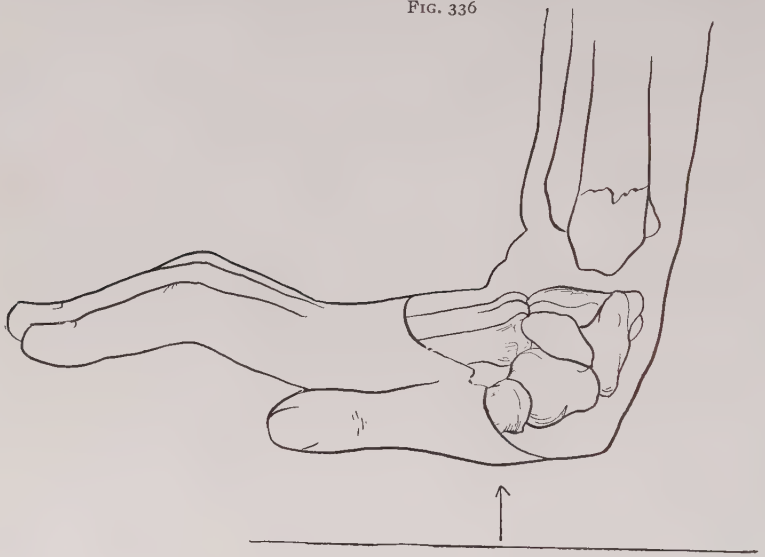
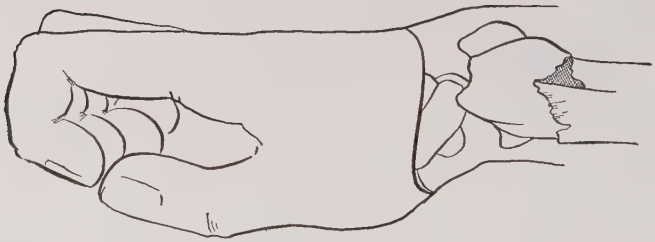


FIG. 337



FIGS. 336 and 337.—Mechanism of Colles's fracture. (336) Force is received on the outstretched, pronated hand and transmitted upward in front of the axis of the shaft of the radius. (337) Displacement of the lower fragment is not only backward and upward, but the lower fragment is also slightly rotated in the direction of supination. (In Fig. 336 the position of the forearm is not correct but should form an angle of 60° or less with the horizontal.)

the articular edge of the radius, which is fractured by arrachement just above this point.

Importance of Adduction or Abduction of the Wrist.— The position of the wrist as to radial or ulnar deviation develops significance from the observations of Schurmeier,[3] who has noticed the greater frequency of articular involvement in fractures produced by "back-fire" injuries as compared with those the result of falls. This dissimilarity he believes is due to the

[2] L. S. Pilcher, *Annals of Surgery*, January, 1917.
[3] H. L. Schurmeier, *Journ. Am. Med. Asso.*, December 31, 1921, p. 2119.

application of the force in a different direction. In the latter type of injury the hand is in dorsi-flexion and radially deflected (abducted). In this position the broad articular surface of the scaphoid is brought into close contact with the articular surface of the radius and the latter escapes injury. In "chauffeur's fracture," on the other hand, the force is applied

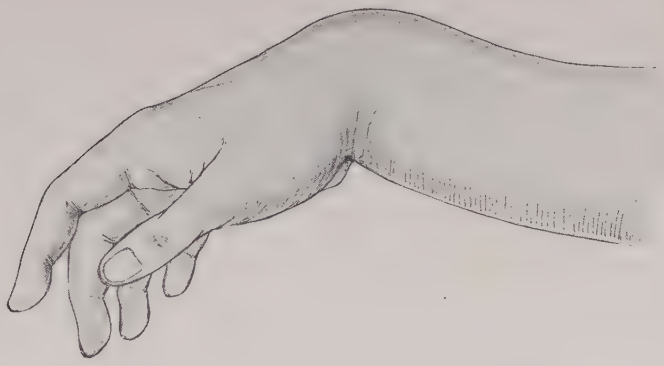


FIG. 338.—Colles's fracture. Characteristic silver fork deformity.

with the hand dorsi-flexed and adducted (ulnar deviation), which brings the articular surface of the radius in contact with the angular or pointed surface of the scaphoid and, therefore, more frequently results in splintering of the joint surfaces.

Types of Fracture.— Much variation exists in the type of fractures, chiefly as regards the amount of comminution and articular involvement.

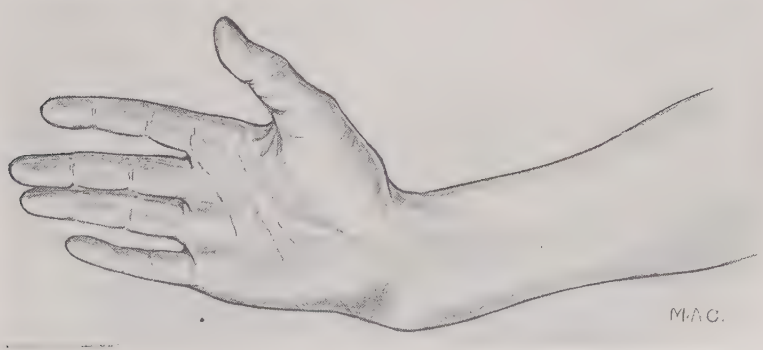


FIG. 339.—Colles's fracture. Characteristic abducted position of the hand with anterior prominence of the head of the ulna.

Simple transverse fracture of the cancellous structure 1.25-2 cm. above the joint margin is the most common type. It may be slightly oblique from the radial to the ulnar side. Comminution is frequently present and may vary from one or more longitudinal fissures extending from the transverse fracture line into the joint surface to general fragmentation of the entire lower end of the bone. Impaction of greater or less

extent is commonly present and is reciprocal in character, the dorsal edge of the proximal fragment being driven into the distal fragment and the anterior edge of the distal fragment piercing the proximal fragment.

The displacement, amount of comminution, and the presence or absence of impaction depend upon the character of the causative force and mode of production. When there is very gross displacement, impaction and comminution are not found to any degree. When, however, the force

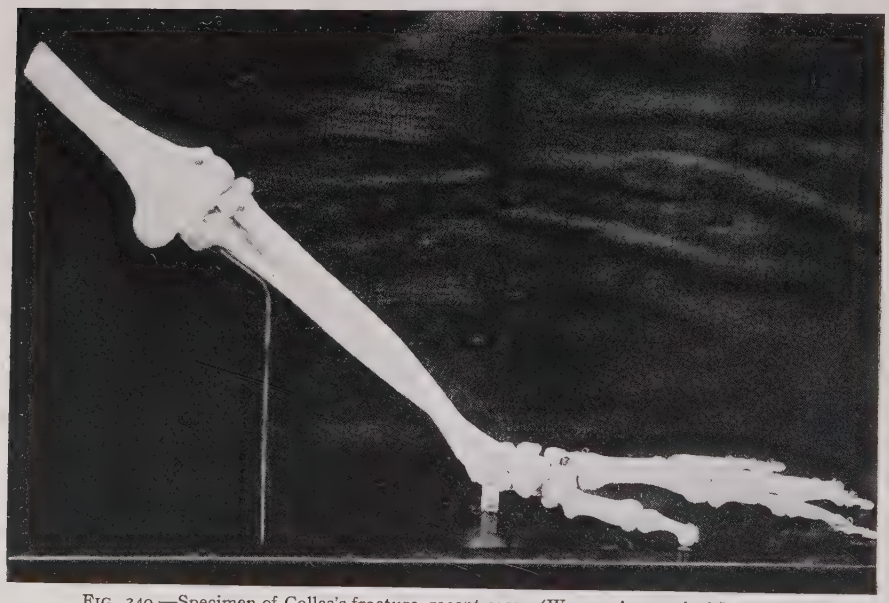


FIG. 340.—Specimen of Colles's fracture, recent case. (Warren Anatomical Museum.)

is applied "end on" to the radius, as in the case of a person sitting down heavily on the dorsi-flexed hand to save himself a fall, an impacted and comminuted fracture is more likely to occur. Back-fire injuries vary widely in the amount of comminution and impaction to which they give rise.

Displacement.— Displacement may be entirely absent or of unimportant degree. In such cases the causative violence is usually slight and comminution does not exist. When displacement is present it consists of several elements and varies in extent. The distal fragment, carrying with it the hand, is displaced backwards and upwards with reference to the proximal fragment. This causes shortening of the radius and draws the hand into the position of abduction (radial deviation). At the same time the distal fragment tilts backward, so that the articular surface of the radius looks backward instead of slightly forward, as is normal. The distal fragment is also slightly rotated in the direction of supination with relation to the proximal fragment. Occasionally the median nerve is bruised or torn.

Ulnar Complications.— The backward and upward displacement entails a disruption of the inferior radio-ulnar joint. If the displacement is marked, strain is exerted through the internal lateral ligament on the

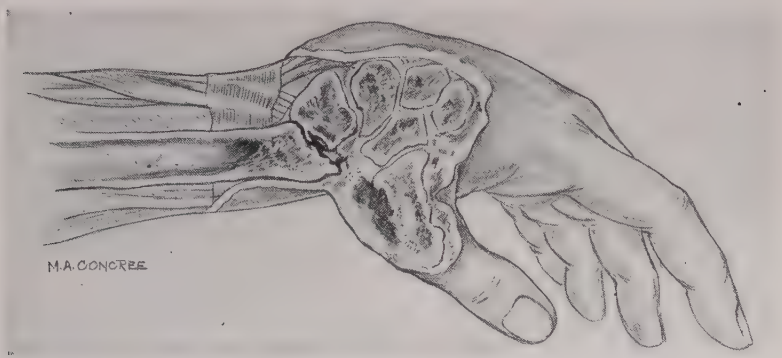


FIG. 341.—Colles's fracture. Appearance of specimen on sagittal section through radius. (Modified from Piersol.)

ulnar styloid and this is frequently fractured. In other cases it is the ligamentous attachment of the fibro-cartilage which gives way instead, or the cartilage may be torn across. With the continuation of the force

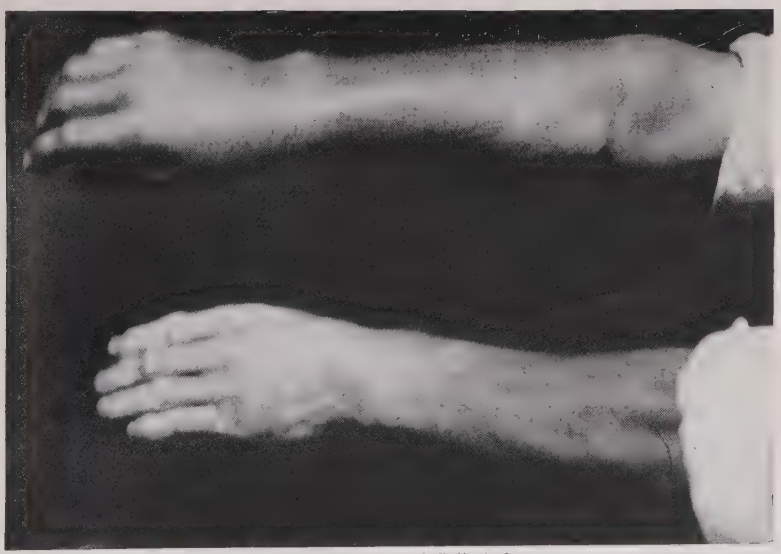


FIG. 342.—Recent case of Colles's fracture.

and the rupture of the structures binding the lower ends of the radius and ulna together, the distal radial fragment may be entirely separated from the head of the ulna, which on account of the accompanying backward and radialward displacement of the hand, appears to be dislocated forward in the wrist.

Diagnosis.—The outline of the hand and wrist, the seat of a Colles's fracture, is compared to that of an inverted dinner fork and hence known as the "silver fork" deformity. This appearance is due to the prominence

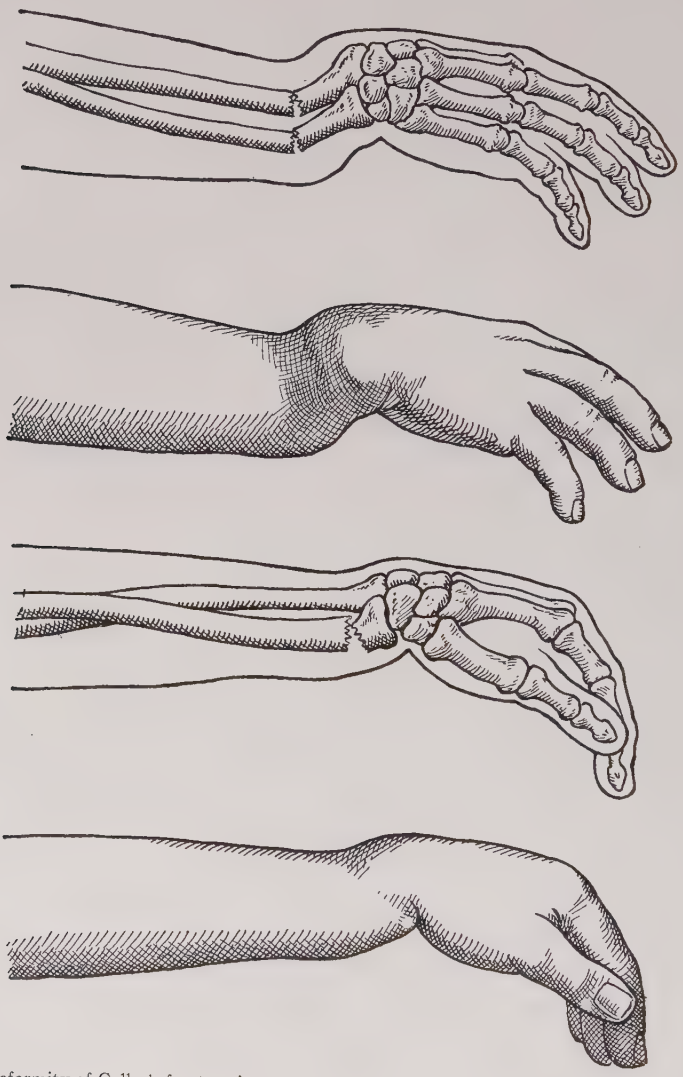
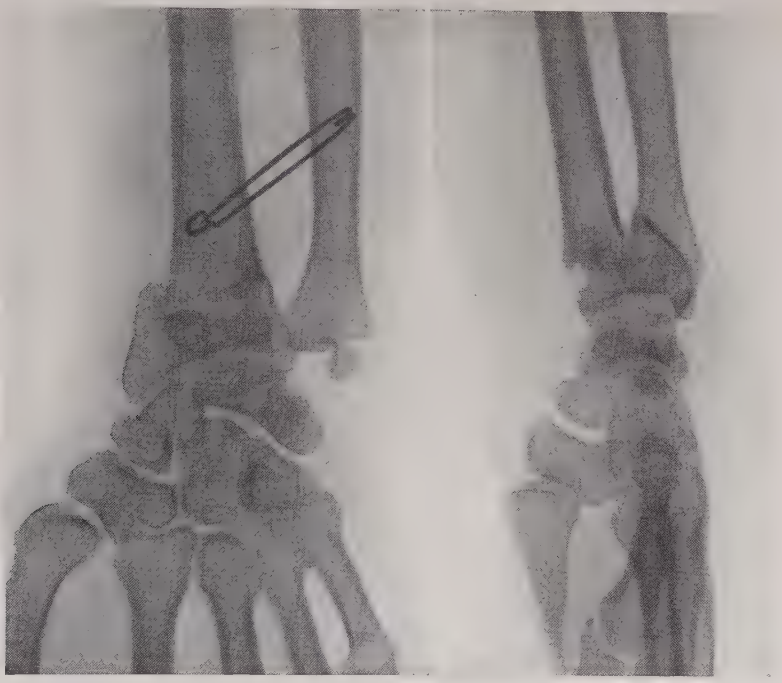


FIG. 343.—Deformity of Colles's fracture in comparison with that caused by fracture of both bones near the wrist. The corresponding position of the bones is shown in outline. (After Helferich.)

of the carpus and distal fragment, the radial deflection of the hand and the slight flexion and ulnar deviation of the fingers. The wrist is swollen and broadened and the patient supports the pronated hand in the sling position.

Fracture with Displacement.— The line of fracture may be distinctly palpable and is extremely tender. Tenderness is also noticeable over the ulnar styloid or over the attachment to it of the ulnar collateral ligament. The prominence formed by the upward and backward displacement of the lower fragment can be both seen and felt, and a depression is discernible just above its upper edge. The distal end of the upper fragment

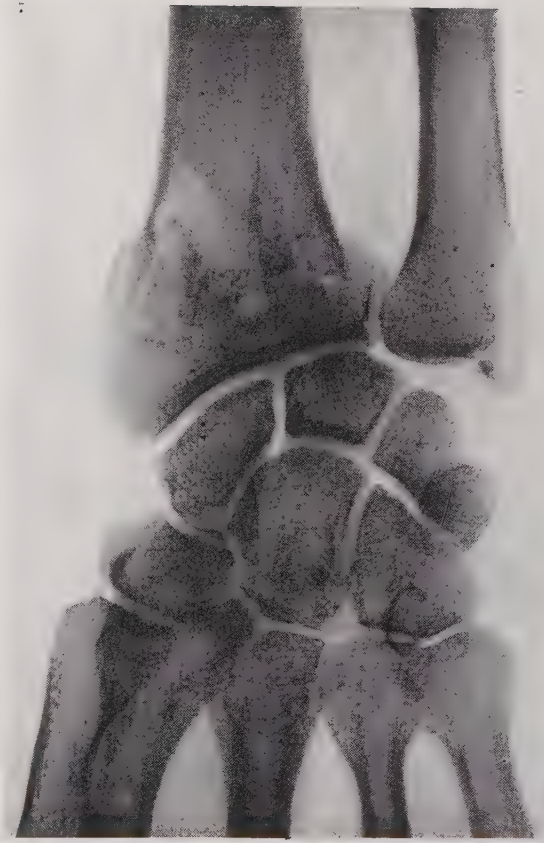


344 345

FIGS. 344 and 345.—Colles's fracture with well-marked deformity. (344) Note the upward displacement of the lower fragment, also the fracture of the ulnar styloid. (345) Lateral view of the same fracture showing posterior displacement. (Edinburgh Royal Infirmary.)

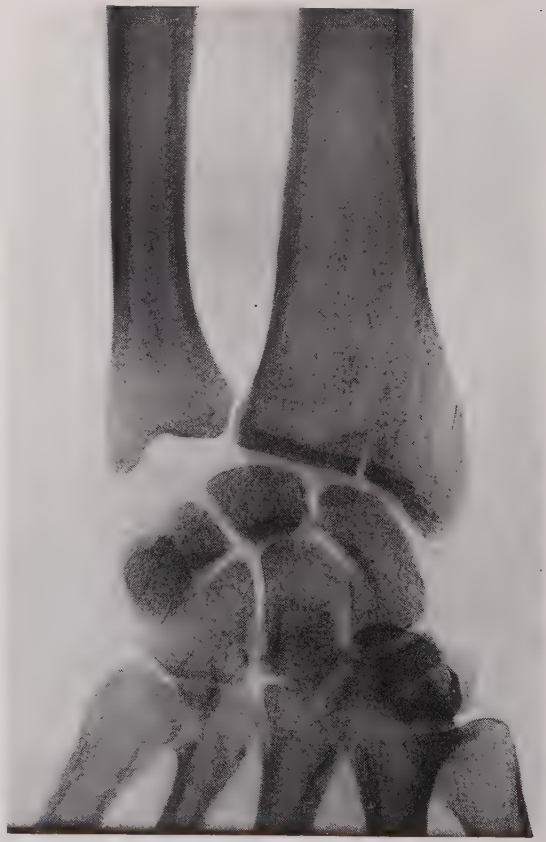
can be felt filling up the natural anterior hollow of the wrist. Crepitus may or may not be demonstrated, but is unnecessary for a diagnosis and should not be searched for. The relative level of the radial and ulnar styloids is always altered in Colles's fracture with displacement, the former now lying as high or even higher than the ulnar styloid instead of 1.25 cm. below it, as is normal. The lower end of the ulna is unduly prominent anteriorly. By measurement the radius is shorter than its fellow of the opposite side. Movements of the wrist and pronation and supination of the forearm are limited and painful.

Fracture without Displacement.—In the case of fracture without displacement, all of these signs may be absent except swelling, pain on motion, and tenderness sharply localized on pressure over the fracture line. Careful



346

FIG. 346.—Comminuted fracture of the lower end of radius. (Fracture Service, M. G. H.)



347

FIG. 347.—Longitudinal fissure fracture of the lower end of the radius. (Edinburgh Royal Infirmary.)

examination and routine use of roentgenograms are necessary to avoid mistakes in such cases.

Roentgenological Examination.—The necessity of roentgenological study in all questionable cases of fracture has been pointed out in the discussion of the general principles of treatment, and in no condition is this more necessary than in fractures of the wrist. Only in this way is it possible to differentiate the variety of bony injuries which may occur in this region and to recognize complicating conditions, such as carpal fractures or dislocations in association with fracture of the radius. Roentgenograms should be made in both the antero-posterior and lateral planes and in some cases stereoscopic plates are advisable. Special features to be noted in the roentgen examination are the amount and character of the displacement, the presence or absence of injury to the ulnar styloid, separation of the bones at the inferior radio-ulnar joint and possible extension of fracture lines into the wrist-joint. In the normal wrist the radial styloid lies one-half to three-quarters of an inch below the ulnar styloid and the articular ends of the radius and ulna together form a smooth concavity. In the lateral view the axis of the articular surface of the radius should be carefully noted. Normally, it faces anteriorly as well as distally, while in case of fracture it is usually tilted so that it faces slightly dorsally, and complete reduction has not been obtained until this deformity has been corrected. Accompanying luxation of the ulna may also be noted in the lateral roentgenogram.

FIG. 348.—Colles's fracture with extreme displacement. Characteristic deformity. Note the prominence of the lower end of the ulna in the palm of the hand. (Edinburgh Royal Infirmary.)

TREATMENT

Fractures without Displacement.—The presence or absence of displacement is the determining factor as regards treatment. In the case of fracture without displacement light protective splinting for a few days,

followed by the use of a bandage, combined with early massage and mobilization of the wrist-joint, are the only measures required (Figs. 349, 350). In children, because of the liability to falls and the possibility of thus suffering fresh trauma, the splinting should be prolonged until union is solid, usually a matter of two to three weeks.

Fractures with Displacement.—In fractures accompanied by displacement, correction of the deformity by manipulative means is necessary.

FIG. 349.—Anterior and posterior plaster splints as used in fractures of the lower end of the radius without displacement.

Incomplete reduction or failure to maintain reduction are the chief factors underlying disappointing final results. Absence of haste and avoidance of undue trauma during the manipulation, followed by painstaking examination to determine if the normal relations have been reëstablished,

FIG. 350.—Plaster casing used in fractures of the lower end of the radius without displacement, holding the wrist in the dorsally flexed position.

are factors essential to success, and to obtain these general anæsthesia is necessary.

Reduction.—The chief obstacles to reduction are impaction and the tension of the fascia and extensor tendons. The first movement in reduction should aim at breaking up the impaction and freeing the bones by forcing the distal fragment and hand backward momentarily into hyperextension. This is followed by firm pressure forward to cause replacement. At this stage we have found the manœuvre employed by Sir Robert Jones very effective. In the case of a right Colles's fracture, the surgeon faces the patient and takes the latter's wrist, rotated into a position midway between

FIG. 351.—Reduction of Colles's fracture. Wrong method of manipulating hand.

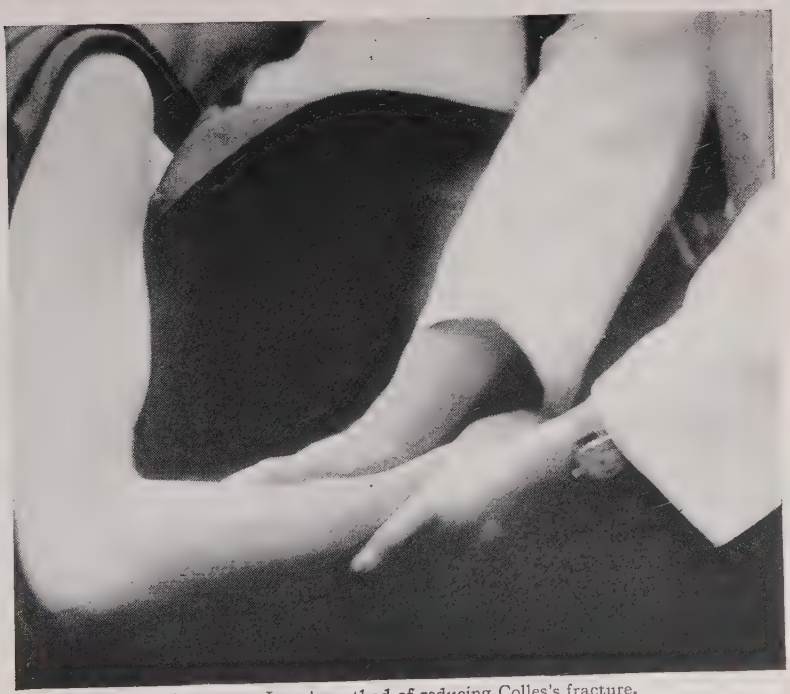


FIG. 352.—Jones's method of reducing Colles's fracture.

pronation and supination, in his own right hand with his thenar eminence and scaphoid tubercle resting against the projecting lower end of the shaft of the radius in the front of the wrist. He then places his left hand on the dorsum of the wrist and the thenar eminence against the dis-

placed lower fragment. The hands are thus in position to exert pressure and counter-pressure on the respective fragments in a direction to cause reduction (Fig. 352). A firm grip, moderate traction and counter-traction, with a twist of the surgeon's left wrist in the direction of pronation, correct the deformity. In cases of shapeless comminution of the lower

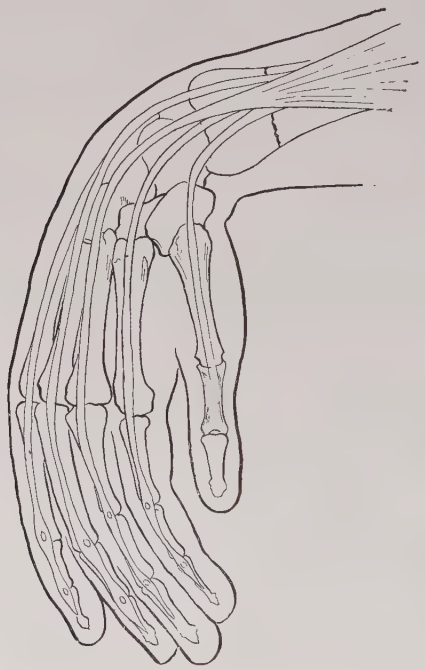


FIG. 353.—Correction is best maintained by a position of extreme palmar flexion, ulnar deviation and pronation. The so-called Cotton-Loder position, which draws extensor tendons tightly across the site of fracture and also exerts traction through the dorsal radio-carpal ligament.

fragment, reduction must take the form of simple direct traction along with moulding of the distal fragments by the fingers and thumb.

Tests of Reduction.—Careful clinical tests for reduction should be made immediately following the manipulation. While supporting the fracture with the fingers of one hand, the movements of the wrist should be tried in comparison with those of the uninjured side. The fragments should be palpated to determine if the abnormal prominence has disappeared and if restoration of the smooth concavity of the anterior surface of the lower end of the radius with its forward projecting articular lip has been secured. Lastly, the levels of the radial and ulnar styloids should be determined to see if the normal relationship has been reëstablished.

Fixation.—The matter of fixation has aroused considerable discussion, some authorities maintaining that if complete reduction is obtained there

is no tendency to redisplacement and that complete fixation is unnecessary. There is no reason why exceptions should be made in Colles's fracture from the plan of treatment employed in other bony injuries, and we believe that the greatest danger to function, next to incomplete reduction, lies in the

FIG. 354.—Cotton-Loder position for fixation of Colles's fracture.

loss of position, once replacement has been obtained. The advocates of the non-fixation treatment base their arguments on the alleged bad results of fixation. That stiff fingers, swollen hands and painful wrists may result from too extensive or prolonged immobilization cannot be

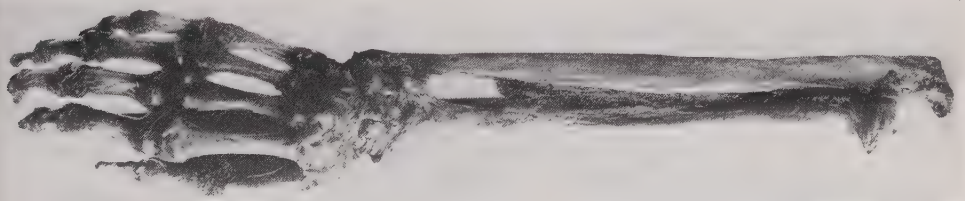


FIG. 355.—Comminuted fracture of the lower end of the radius, healed with deformity. (Army Medical Museum.)

denied, but the solution of the problem lies not in the withholding of all fixation, but rather in the use of splints properly applied. Early and free use of the fingers and hand is greatly to be desired, but this cannot be expected when use causes pain, as is the case when the fracture is unsupported. Adequate support of the fracture may be obtained with fixation of the wrist, leaving the fingers, thumb and elbow free to function.

The Cotton-Loder Position.—Position is of considerable importance. Following the plan of Cotton [4] and Loder, we may proceed from the standpoint that if the ulna is the fixed point about which the hand is

FIG. 356.—The Cotton-Loder position in the treatment of Colles's fracture. This position is secured by the application of a plaster cast which should be immediately split, the two portions being retained in position by a bandage, as shown.

displaced, it should be made the fixed point for effecting and maintaining reduction. Since the displacement of the lower fragment and hand is

FIG. 357.—The Cotton-Loder position for Colles's fracture. Instead of a solid plaster casing, moulded plaster splints may be prepared as shown.

in the direction of extension and supination, correction is to be obtained by the positions of palmar flexion and pronation. Since the hand deviates to the radial side in the deformed position, it should be adducted or devi-

[4] Cotton, F. J., *Boston Med. and Surg. Journ.*, December 4, 1919, p. 651.

ated to the ulnar side in order to maintain the correction. Certainly, in our experience, the Cotton-Loder position of palmar flexion, pronation and ulnar deviation has proved its value in securing and maintaining reduction in difficult cases, but it is not required in simple uncomplicated cases. The position itself is about the worst possible one from the standpoint of early restoration of function and should be modified as soon as the fragments begin to unite, usually at the end of about 7-10 days.

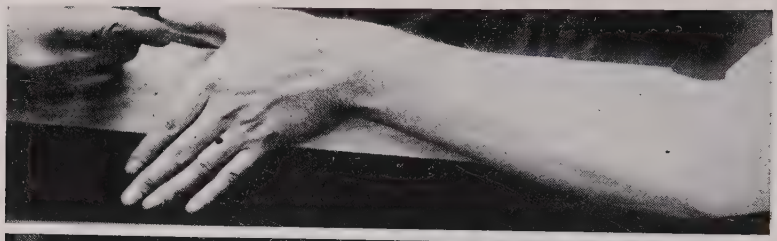
Choice of Position.— Dogma is particularly dangerous with regard to the treatment of Colles's fracture because of the great variation in severity and degree of displacement shown by different cases. Choice of the position for fixation should be governed by the extent of comminution, the amount of displacement and the tendency of the deformity to recur, as determined at the time of the manipulation. In cases without displacement where protection alone is needed, we may use the optimum position for fixation and immobilize in the " cock-up " or dorsi-flexed position (see Fig. 349). In displaced fractures without much comminution or tendency to recurrence we may use a position of moderate palmar flexion and ulnar deviation, but with severe deformity and comminution and difficulty in reduction the extreme Cotton-Loder position is a valuable aid in securing and maintaining correction.

Choice of Splints.— The type of splinting to be employed is to a large extent determined by the position selected for fixation. Only with plaster of Paris can the full Cotton-Loder position and the "cock-up" position be obtained. Plaster has the additional advantage of being malleable, so that moulded support of the palmar arches may be secured. Flat wooden splints may be used in the ordinary case with moderate displacement when a position of ulnar deviation and moderate palmar flexion is alone necessary. Such splints, when properly padded, are fully as satisfactory as plaster splints, but there is danger of insufficient padding and flattening of the wrist and hand.

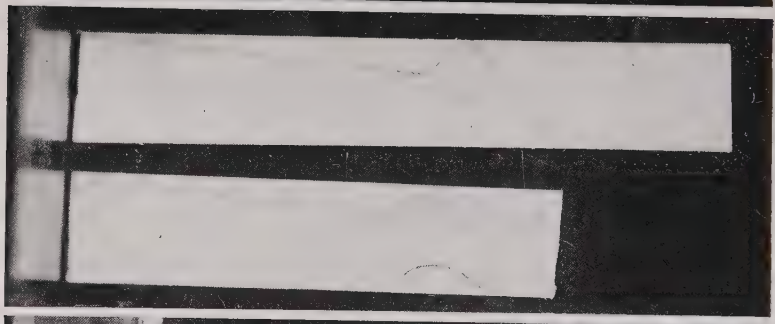
Plaster Gutter Splints.— Plaster is best used in the form of moulded gutter splints. Two of these are necessary, one each for the anterior and posterior surfaces of the arm. They may be quickly and readily made from 10-12 layers of plaster bandage, which are then applied to the forearm and wrist and secured by circular turns of gauze bandage (Fig. 381). The hand and wrist are supported in the desired position until the plaster has hardened, when the latter is trimmed to allow full motion and approximation of the fingers and thumb.

Wooden Splints.— Wooden splints may be prepared as shown in the illustrations (Figs. 358 to 364). The width of the splints should be slightly less than the width of the arm. The pistol grip is comfortable and allows the maintenance of the position of adduction or ulnar devia-

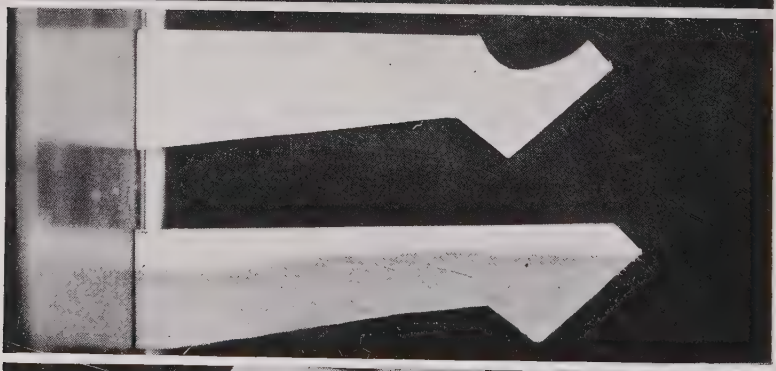
358



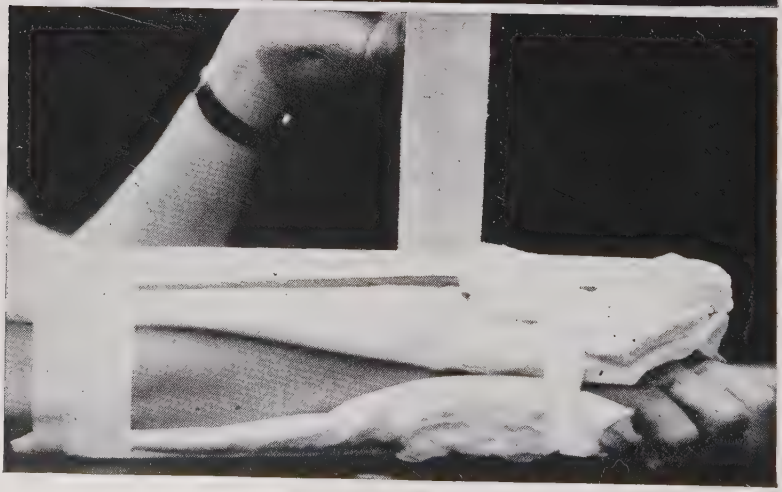
359

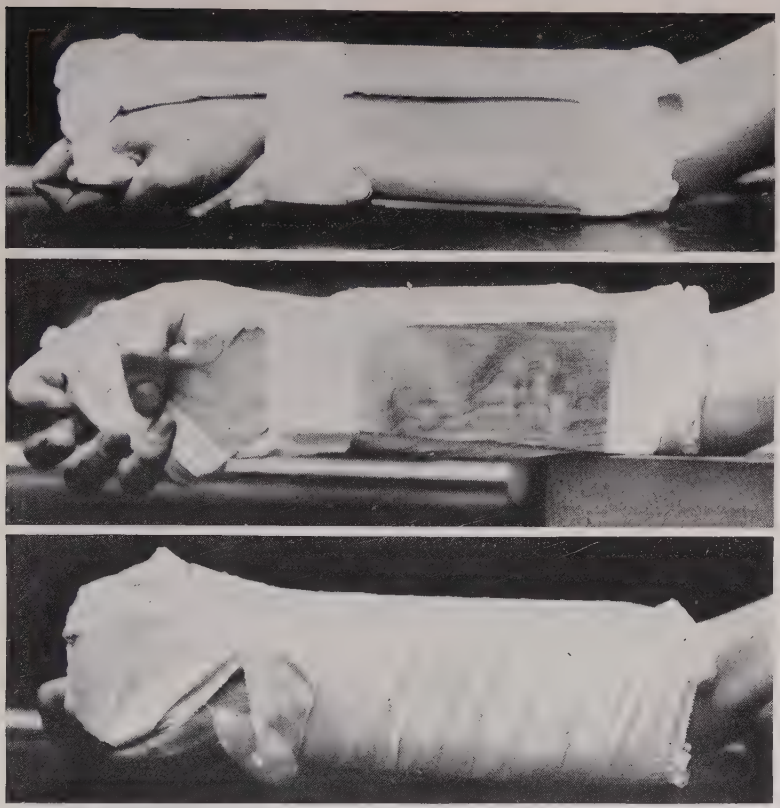


360



361





FIGS. 358, 359, 360, 361, 362, 363 and 364.—Anterior and posterior wooden splints for Colles's fracture. (358) Marking out the splint. Measurements are taken from the uninjured hand. The points marked are the base of the thumb, web of the thumb, line of the metacarpo-phalangeal joints, and the junction of the ulnar portion of the forearm with the hand. (359) The points previously marked out are then joined by lines as shown. A semicircular portion is marked out for the thenar eminence. The posterior splint is slightly longer than the anterior one and lacks the notch for the thumb. (360) The splints are then cut out as shown. (361) Abundant padding is necessary in the application of the splints and special padding is inserted to fill the hollow under the anterior surface of the wrist in order to allow a position of slight palmar flexion. The space between the dorsum of the hand and the splint should also be filled with padding. (362) The splints are fixed in place by strips of adhesive. (363) Opposition of the thumb to the tips of each of the fingers should be possible with the splints in place. (364) The dressing is completed by the application of a bandage.

tion. They should be padded abundantly with sheet wadding and a special pad placed under the distal end of the proximal fragment, and a second over the dorsum of the hand to fill in the space between it and the splint caused by the moderate flexion of the wrist. The splints are prepared previous to reduction and then at the proper moment fastened in place by tapes of adhesive encircling the upper and lower ends and a third band at the level of the wrist. The splints are then wrapped with bandage to secure firm, even compression. The palmar splint extends from the elbow to the distal palmar crease of the hand, which corresponds to the level of the metacarpo-phalangeal joints and should permit free flexion of the fingers.

Post Reduction Skiagrams.—Immediately following reduction new roentgenograms should be secured to determine the position of the fragments with the splints in place. If reduction is incomplete, it must be determined what further steps are necessary. Not only the various local factors of injury must be considered, but also the age, general physical condition, occupation and social environment of the patient. In many cases with severe comminution complete anatomical restoration cannot be obtained, even by operative means, and one must be content with the

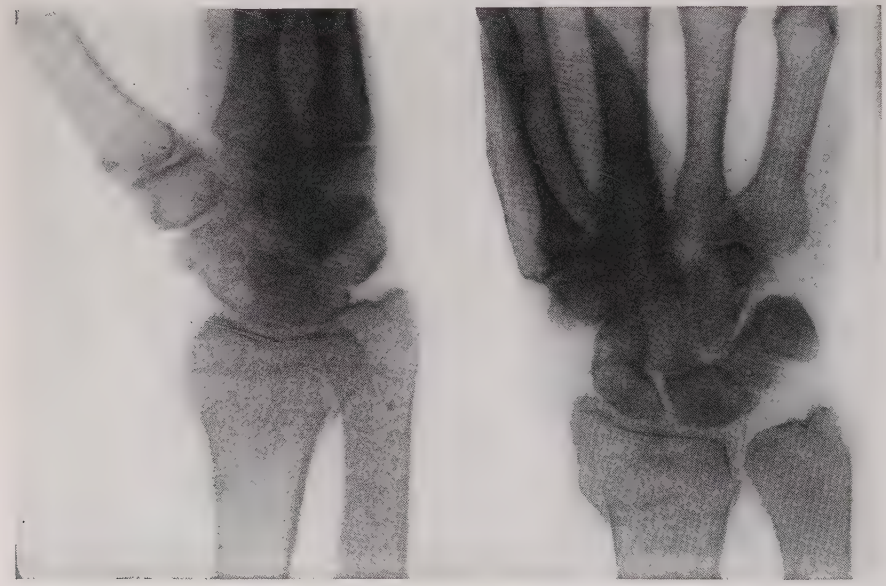
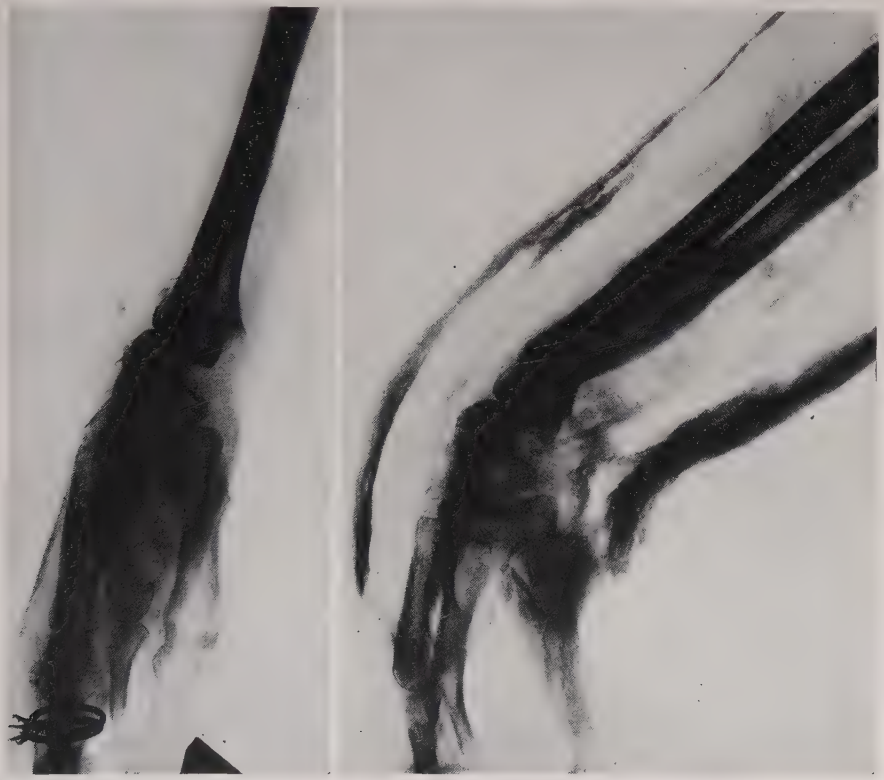


FIG. 365.—Impacted transverse fracture of the lower end of the radius. (Edinburgh Royal Infirmary.)

correction obtained. In other cases with simple transverse fracture lines the reduction should be repeated. Much depends upon the skill and experience of the individual surgeon, and certain it is that in skilled hands open reduction of recent cases of Colles's fracture is rarely necessary.

After-treatment.— The after-treatment must be conducted with care. The patient should be seen the day following reduction and the fingers tested for evidence of circulatory disturbance. It is usually unnecessary to take down the splints before the end of 3-4 days. During this period a sling is worn. At this time the dressing should be opened, the anterior splint being left *in situ* to provide support. Gentle massage may be administered and the splints reapplied. The sling is discontinued and the patient instructed to move the fingers and thumb frequently. At the end of one week active use of the hand for the performance of light tasks should be encouraged and daily removal of the dorsal splint for massage may be permitted. If the wrist has been immobilized in the Cotton-Loder

position, the arm should be transferred to an anterior cock-up splint at the end of about ten days. Fixation should be continued for a total period of 2-4 weeks. Usually one splint may be removed one week before the total discontinuance of fixation. Warm baths and massage are very useful when the splints are removed. Active movements of the wrist and



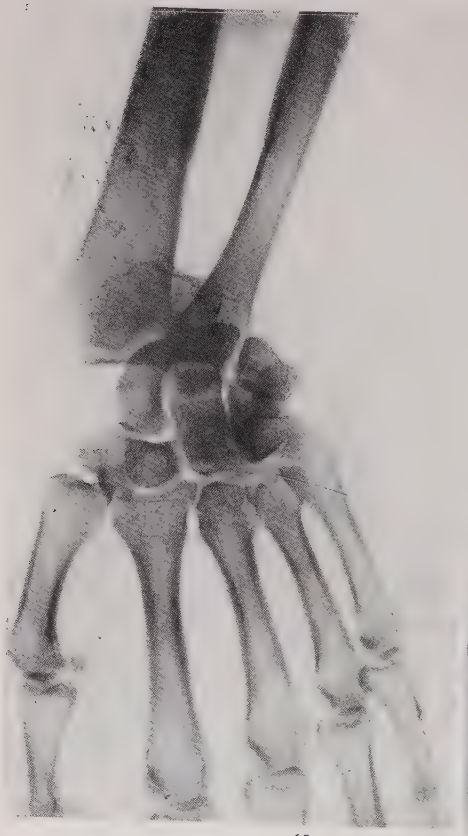
366 367

FIGS. 366 and 367.—Colles's fracture. Partial displacement. (366) Before reduction. Note the backward tilting of the lower articular surface of the radius. (367) Following reduction. Note restoration of normal plane of the articular surface. Cotton-Loder position.

inferior radio-ulnar joint should be encouraged and resistive exercises for the fingers should be persevered with until full power and function return. Some form of suitable occupational therapy may also be planned with advantage. Movements of rotation should be begun early, the surgeon supporting the seat of the fracture with his fingers.

Prognosis.—Rarely is there delayed union and the fracture almost invariably unites eventually. Loss of function and weakness of grasp or pain on use usually have their primary cause in incomplete reduction or failure to maintain good position. Radial deviation of the hand, such as obtains with incomplete correction of the deformity, is of itself a position of weakness, and in addition, the tendons work at a mechanical

disadvantage because of having to pull over a bony projection. The alteration in the axis of the articular surface causes limitation of certain movements and may be responsible for the setting up of a reactionary arthritic change in the joint. Involvement of the articular surface by longitudinal



368

369

FIGS. 368 and 369.—(368) Fracture of the lower end of the radius with complete displacement. Gross deformity. (369) Same fracture following reduction. Position maintained by wooden splint. (Fracture Service, M. G. H.)

fissure fractures may also be the cause of arthritic manifestations in the wrist.

Circulatory derangement from the effects of the injury or occasionally as the result of too tight or too prolonged splinting may also lead to functional impairment by causing venous stasis, œdema and fibrous proliferative changes, with consequent adhesion of the tendons.

Open Reduction.— Persistence of deformity of a type to cause disability despite all efforts at closed reduction necessitates open correction. Fortunately this is a rare occurrence. The approach to the seat of a Colles's fracture is best made through a dorsal incision in the space between the

common extensors of the fingers and the radial extensors of the carpus. The periosteum is incised and the fracture line exposed. The fragments are mobilized by inserting between them a thin bladed osteotome, and by means of this, while exerting traction on the hand, the distal fragment is levered forward into normal position. There is little tendency for redisplacement to occur and internal fixation is rarely required. The wrist is supported in the Cotton-Loder position during closure of the

FIG. 370.—Reduction of Colles's fracture with Thomas' wrench. The distal blade is in contact with the lower end of the upper fragment, while the proximal blade rests on the lower fragment and levers it forward.

incision and retained in this position by the immediate application of moulded plaster splints.

Malunion.—In recent cases of malunion it is possible sometimes to secure replacement by closed reduction, using Thomas' wrench. By applying the blades to the wrist with the handle pointing dorsally and slightly proximally and directing the force in such a way as to first increase the deformity, the soft union is broken up and the fragments mobilized. The wrench is then reapplied with one blade on the distal fragment and the other on the lower end of the upper fragment and the bones levered back into correct alignment (Fig. 370). When the case is of longer standing than six weeks, open operative treatment is indicated, with osteotomy of the radius at the level of the fracture. The distal fragment is then pushed forward and the subsequent steps are the same as in the open treatment of a fresh fracture.

LUXATION OF THE ULNA

Among the complicating sequelæ of a Colles's fracture is that of a partial luxation of the lower end of the ulna. It may move backward and forward with rotational movements of the forearm and has been

371

372

FIGS. 371 and 372.—Convalescent treatment of fractures of the wrist. Laced leather wristlet, giving partial protection of the wrist-joint.

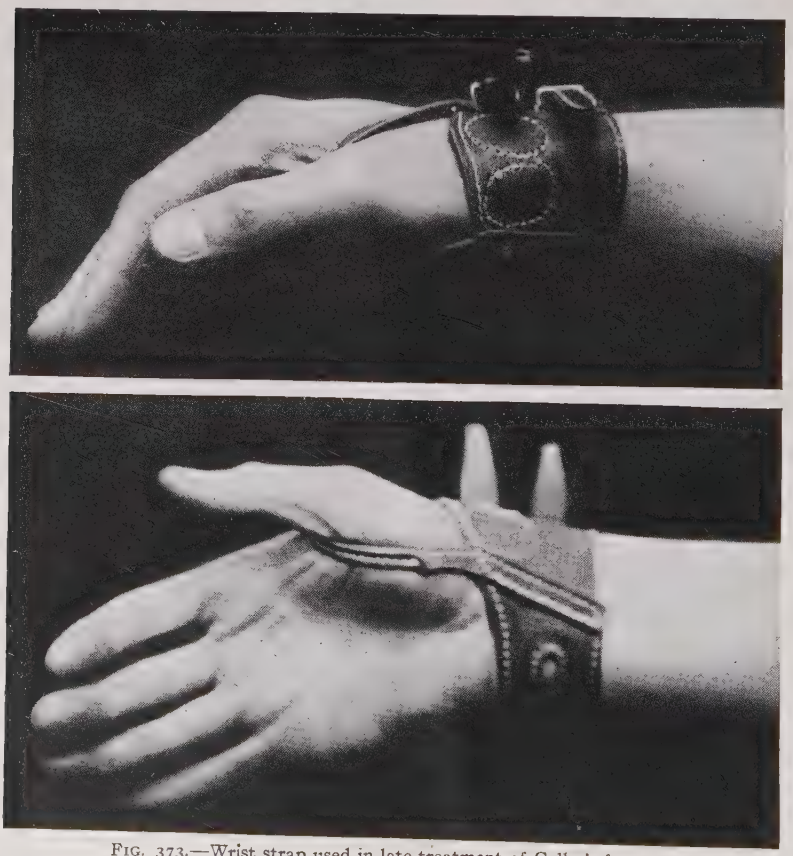


FIG. 373.—Wrist strap used in late treatment of Colles's fracture.

known to cause symptoms from ulnar nerve irritation. Relief from such a state of affairs, as also in the majority of other undesirable sequelæ of this fracture, lies in a proper appreciation of the effects of the original displacement and its complete correction at the time of the accident. In old cases with trouble from this cause and deformity still present, relief is to be obtained, not by operative procedures on the ulna, but rather by osteotomy of the lower end of the radius and correction of the malunion (see page 267).

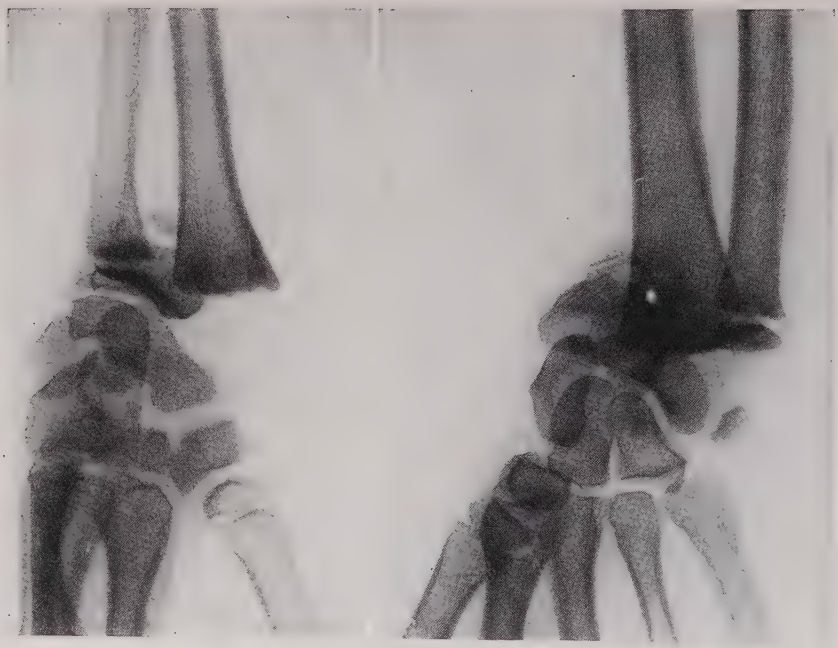
B. SEPARATION OF THE LOWER RADIAL EPIPHYSIS

Occurrence.—This injury is usually produced by the same kind of violence as that which causes Colles's fracture and is more frequently encountered in boys than in girls. The common age period is between twelve and eighteen. Before the age of twelve the epiphysis is relatively small and tough from the predominance of the cartilaginous elements. At this period a fall on the outstretched hand is more apt to cause fracture of both bones of the forearm or a dislocation of the elbow than a separation of the epiphysis. After the age of twelve, the physical characteristics of the epiphysis alter to approach the adult form, and diastasis occurs more readily.

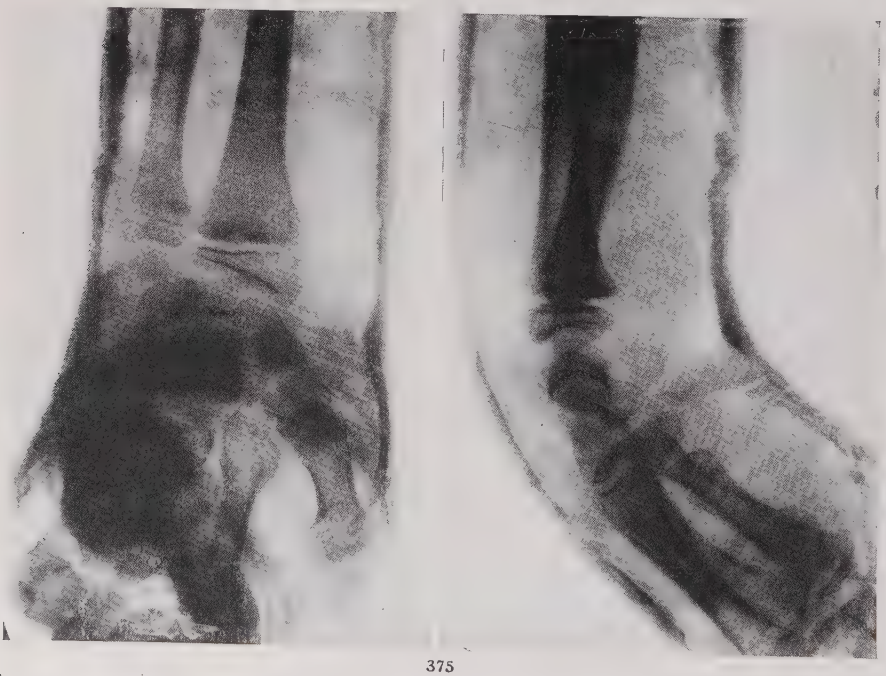
Pathology.—The separation seldom occurs entirely at the epiphyseal junction, the line diverging and passing through the posterior portion of the metaphysis as a fracture. The injury is often accompanied by fracture of the ulnar styloid, or occasionally by separation of the distal ulnar epiphysis, which lies at practically the same level. The displacement is similar in character to that in Colles's fracture, the mechanism being the same. The transverse character of the fracture line, its location and the age of the patient help to distinguish the type of injury. The treatment is in all respects similar to that of Colles's fracture. Retardation of growth is always a possibility after these injuries, and this should be made clear to the parents.

C. OBLIQUE FRACTURES OF THE LATERAL ARTICULAR BORDER OF THE RADIUS AND OF THE RADIAL STYLOID

Causation.—Many fractures of the lower end of the radius are oblique in character rather than transverse, and this may occur in any direction, the fracture line sloping upward from the distal extremity and either forward, backward, inward or outward. Of this group of injuries, by far the most common is the oblique fracture extending upward and outward from the articular surface of the radius, separating a larger or smaller triangular fragment which includes the radial styloid and the outer articular border. The injury results either from a fall on the outstretched hand or from "back-fire" trauma, and it is probable that the factor which determines the type of fracture is the abducted position of



374



375

FIGS. 374 and 375.—(374) Separation of the lower radial epiphysis. Gross displacement. (375) Following reduction. Retention in Cotton-Loder position by plaster splints. (Fracture Service, M. G. H.)

FIG. 376.—Oblique fracture of the lower end of the radius.
(Edinburgh Royal Infirmary.)

FIG. 377.—Fracture of the base of radial styloid.
(Edinburgh Royal Infirmary.)

the hand at the moment of injury. In the opinion of Pilcher, forcible dorsi-flexion of the hand with cross-breaking strain exerted through the anterior common ligament is the cause, just as in Colles's fracture, only with the difference that the inner part of the middle of the three bands into which the anterior ligament is divided gives way and the strain is transmitted through the powerful outer band to the base of the radial styloid, where it is inserted.

Treatment.—Displacement is rarely of great degree, and when present is usually in a backward, outward, and upward direction. Reduction is obtained as in Colles's fracture, and the wrist should be immobilized with the hand in moderate palmar flexion and ulnar deviation, special emphasis being placed upon the latter.

Fractures of the Styloid.—Fracture of the tip of the radial styloid occurs as a form of sprain fracture from forcible adduction of the wrist and is of comparatively slight importance. Simple protective splinting in the cocked-up or dorsi-flexed position for a period of two weeks, followed by an equal period of restricted use, is all that is necessary in the way of treatment.

D. FRACTURE OF THE POSTERIOR ARTICULAR MARGIN

Pathology.—A fairly common injury of the lower end of the radius is an oblique fracture extending upward and backward with separation of a triangular fragment which includes the posterior lip and part of the inferior articular surface, the so-called Barton's fracture. Like Colles's fracture, it is produced by a fall on the outstretched pronated hand, but there is probably a slight difference in the mechanism due to the forearm meeting the ground in a more horizontal plane and the predominance of a backward dislocating force at the wrist-joint. This is opposed by the posterior articular margin which is broken off, allowing the carpus and attached radial fragment to luxate posteriorly.

Diagnosis.— When there is severe displacement the condition is apt to be confused with pure dislocation of the carpus or Colles's fracture and when it is only slight, a roentgenogram is necessary for the determination of the exact lesion. Roentgenograms in the antero-posterior plane may be quite deceptive, and only in the lateral view is the displacement shown. The fracture is important, as it affects the mechanics of the radio-carpal joint, and failure to recognize it and obtain proper reduction may later result in pain and weakness of grasp.

Treatment.— Reduction under anæsthesia is readily accomplished, but in order to maintain the correction it is necessary to immobilize the wrist with the hand in full palmar flexion, ulnar deviation and pronation. Unlike Colles's fracture, there is little stability of the fragments in the reduced position, and it is only by making tension on the posterior capsule and

dorsal tendons, with traction on the carpus by means of the position of palmar flexion and ulnar deviation of the wrist, that recurrence of the deformity can be prevented. Fixation is accomplished with anterior and posterior moulded plaster splints leaving the fingers and thumb free. This position should not be maintained for more than 7-10 days, owing to its

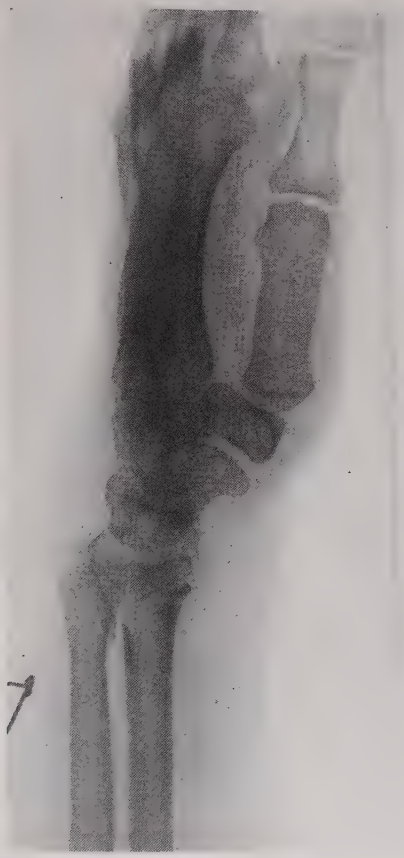


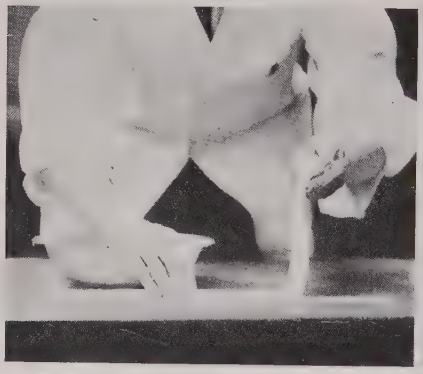
FIG. 378.—Roentgenogram of Smith's fracture, or Colles's fracture reversed. (Edinburgh Royal Infirmary.)

bad influence on hand and wrist function. At this time the bones are beginning to unite and the wrist may, with considerable advantage, be transferred to a moulded plaster cock-up splint, where it is kept for a period of one to two weeks longer with daily massage and gentle mobilization of the articulations.

II. FRACTURES FROM FALL OR BLOW ON DORSUM OF HAND WITH FLEXION OF THE WRIST

Owing to the extreme infrequency of accidents in which severe force is applied to the dorsum of the hand, in comparison with those in which trauma is exerted on the palm from the opposite direction, fractures from

the former cause constitute but a small percentage of all the injuries of the lower end of the radius. Nevertheless, several distinct fracture entities have been recognized and described, the mechanism in all being more or



379

380

381

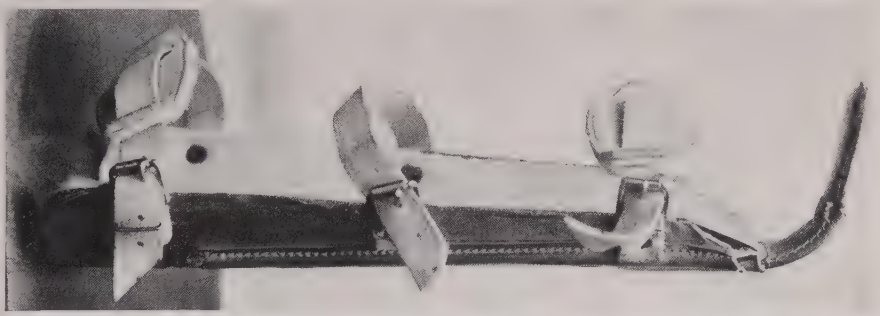
FIGS. 379, 380 and 381.—The manufacture of moulded plaster splints. (379) Plaster bandage is rolled back and forth, making a strip of the desired length and width. (380) Over a layer of cotton or felt padding, this is applied to the part and made to conform to the surface by the application of a gauze bandage. (381) Short cock-up splint completed. This is the type of dressing that is applied at the end of ten days when the Cotton-Loder position has been used.

less the same; namely, a fall on the back of the hand or blow received on the dorsum of the hand and wrist.

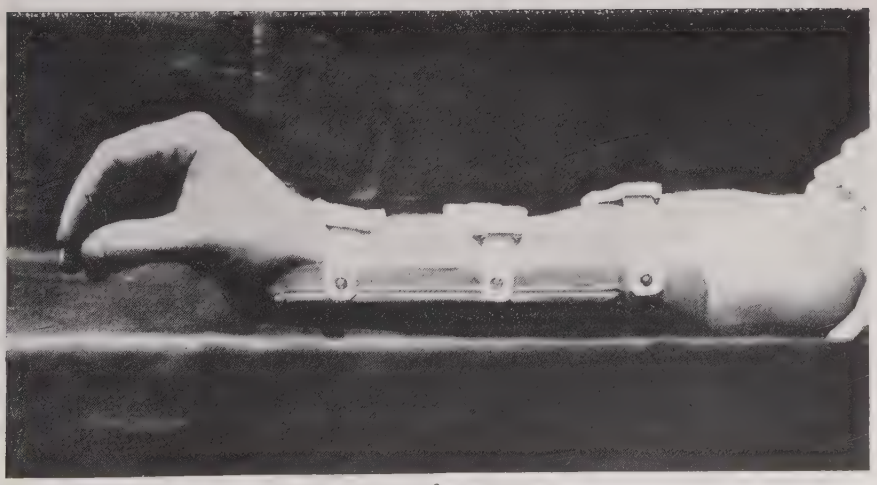
A. SMITH'S FRACTURE (COLLES'S FRACTURE REVERSED)

Types of Injury.— This is a transverse or oblique fracture of the lower cancellated extremity of the radius with the obliquity directed upward and forward. Roberts has collected twenty-four clinical observations

FIG. 382.—Anterior plaster splint showing how it is moulded to support the palmar arch. It is trimmed along the line of the distal palmar crease in order to allow free flexion of the fingers.



383



384

FIGS. 383 and 384.—Light metal cock-up splint, leather covered, holding the wrist in the position of optimum function, when long-continued support is necessary.

and thirty-one specimens. Displacement of the lower fragment occurs in an upward and forward direction. The diagnosis depends upon the recognition of a deformity which is just the reverse of that seen in Colles's fracture.

B. FRACTURE OF THE ANTERIOR ARTICULAR MARGIN (BARTON'S FRACTURE REVERSED)

This is an oblique fracture of the projecting anterior lip of the radius with separation of a triangular fragment from the articular border. The fragment may be displaced forward and upward and the injury may be complicated by a partial anterior luxation of the carpus. This injury may also result from arrachement by hyperextension of the wrist.

C. SEPARATION OF THE LOWER RADIAL EPIPHYSIS

Very rarely the lower radial epiphysis may be separated by a force acting in the anterior rather than in the dorsal direction, as is usual (see page 285). When this occurs, the displacement is in the forward and upward direction.

TREATMENT

The treatment of these injuries consists essentially in manipulative reduction under anæsthesia, followed by a period of fixation of two to four weeks. Owing to the fact that the injury is the result of force acting in the direction of flexion, reduction should be secured and maintained by a position of extension. The forearm should be immobilized on a moulded plaster splint extending from the elbow to the metacarpo-phalangeal joint with the wrist dorsi-flexed, the palmar arch properly supported and the thumb and fingers free (Figs. 381, 382). With proper treatment the prognosis in this group of cases should be better than in those due to force acting from the opposite direction, because of the great advantage in being able to immobilize in the optimum functional position. Early massage, active and passive mobilization of the various articulations, and free use of the fingers are as important as in all other wrist injuries.

II. INJURIES OF THE WRIST-JOINT

I. DISLOCATION OF THE INFERIOR RADIO-ULNAR JOINT

Pathology.—Anterior luxation of the head of the ulna, usually incomplete, has already been mentioned as a part of the displacement complex in Colles's fracture (see page 267). Posterior dislocation of the lower end of the ulna with or without accompanying fracture of the ulnar styloid may occur independently of fracture of the radius, but is rarely encountered. The injury apparently is caused by a severe twisting form

of violence with hyperpronation of the forearm. The hand is held in the position of pronation, rotational movements of the forearm are restricted, with pain referred to the inferior radio-ulnar joint, and the head of the ulna is prominent posteriorly.

Treatment.—Reduction is readily accomplished by strong traction on the hand with forward pressure on the head of the ulna, followed by

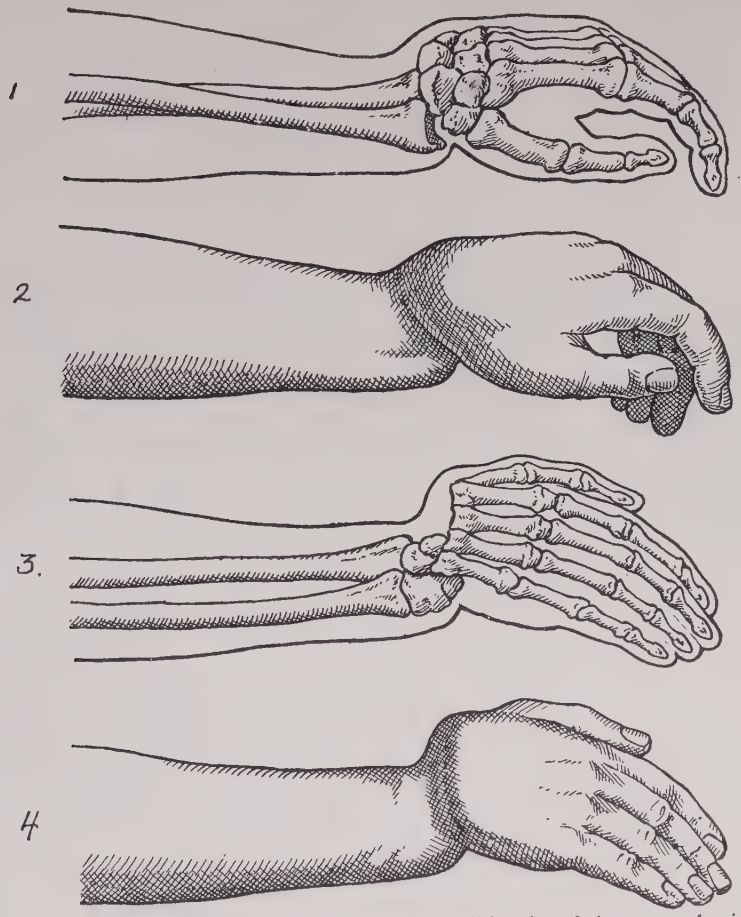


FIG. 385.—Dislocation of the wrist. (1 and 2) Posterior dislocation of the carpus showing skeletal deformity and change in outline of the wrist. (3 and 4) Carpo-metacarpal dislocation of the wrist. (After Helferich.)

sharp supination of the forearm. The wrist should be fixed in the supinated position with the hand dorsi-flexed on a moulded plaster cock-up splint. Immobilization should be maintained for three weeks, in order to allow strong healing of the torn ligaments, without which a condition of chronic recurrent luxation is probable. The dislocation, even when reduced, is not easy to hold and a wrist strap should be worn for some time (Fig. 373).

Chronic Recurrent Luxation.— The authors have operated in a case of chronic recurrent luxation of six years' duration, the patient complaining of pain and weakness when performing tasks requiring movements of pronation. The attachments of the discus articularis and ulnar lateral ligament were found torn across and were repaired by the introduction of a fascial ligament passing from the ulnar portion of the disc to the posterior surface of the head of the ulna, where it was anchored in the bone. This resulted in a stable and painless wrist with good function.

2. DISLOCATION OF THE RADIO-CARPAL JOINT

Causation.—Dislocation of the radio-carpal joint is a rare injury, due to the flexibility of the wrist, the strength of the ligaments which support it, and the relatively greater weakness of the lower end of the radius. It

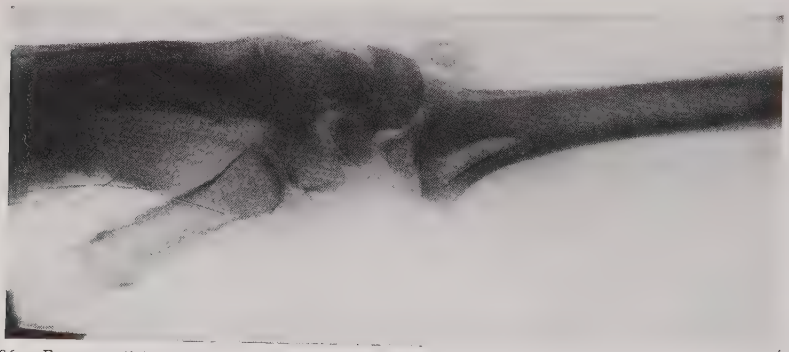


FIG. 386.—Fracture dislocation of the wrist. Both anterior and posterior articular borders of the radius have been fractured, the anterior rim probably by avulsion. (Edinburgh Royal Infirmary.)

is produced by severe violence, such as a fall from a height on the extended palm. Although displacement may occur in either the forward or backward direction, the dorsal variety is the more frequently encountered. Dislocation is accompanied by extensive injury to ligaments and tendons, and may be associated with severe bony injuries as well.

Diagnosis.— In the clinical examination of the complete dorsal type, the articular surfaces may be palpated in their new position. When swelling has taken place, however, it may be difficult to distinguish a dorsal dislocation of the wrist from a Colles's fracture or separation of the lower radial epiphysis, either of which may complicate the dislocation. In the event of an uncomplicated dislocation, the mutual relationship of the styloid processes remains unchanged and the dorsal projection caused by the carpus is situated more distally than that of a Colles's fracture; in a dislocation too, the palm is shortened and the fingers are held in greater flexion than in a Colles's fracture. Attention should be drawn to the fact that the posterior articular lip of the radius may be fractured and carried backward with the carpus (see page 288).

Treatment.—Direct traction on the hand and pressure applied directly to the carpus are the measures to be used in effecting reduction. In compound dislocations the injury is usually so extensive as to necessitate amputation. When conservative treatment is possible and reduction has been accomplished, the wrist should be splinted in the "cock-up" position

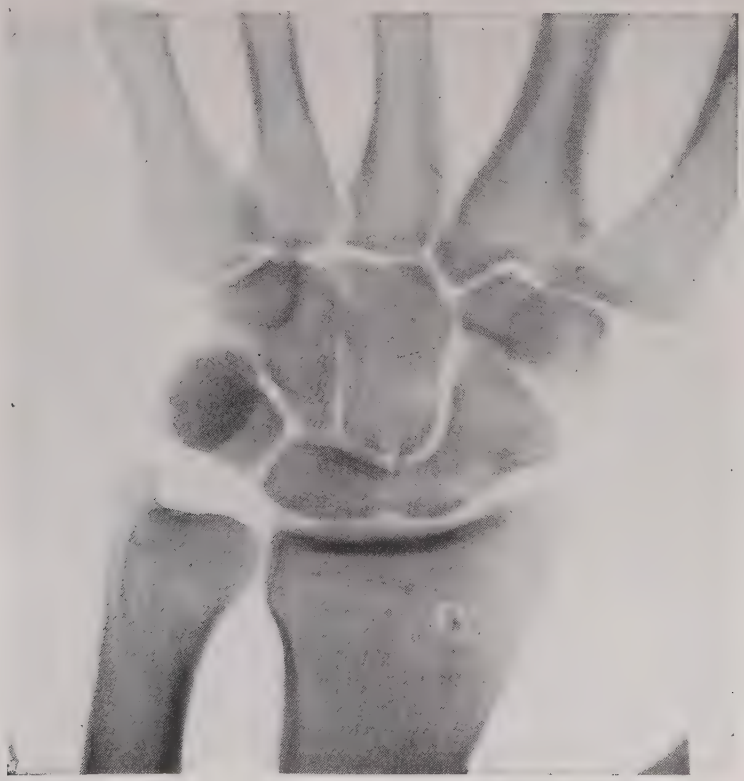


FIG. 387.—Fracture of the carpal scaphoid without displacement. (Edinburgh Royal Infirmary.)

on a long, anterior, moulded plaster splint extending from the elbow to the finger tips and including the thumb, which is fixed in the position of grasp (Fig. 389).

3. CARPAL INJURIES

A. FRACTURE OF THE SCAPHOID

Frequency.—By far the most common traumatic lesion of the carpus is fracture of the scaphoid. In Bizarro's [5] collection of 123 cases of carpal injury, the scaphoid was fractured alone in 68 or 55 per cent., and in association with other bony lesions, such as fracture of the radius or ulna or involvement of the other carpal bones in 38, or 30 per cent., giving a

[5] A. H. Bizarro, *Surg., Gyn. and Obstetrics*, May, 1922.

total occurrence of 106, or 86 per cent. This does not mean that carpal injuries are of themselves encountered with great frequency, as evidenced by the fact that in 3000 consecutive admissions to the special fracture out-patient department of Guy's Hospital, Todd found only nine cases of fracture of the scaphoid. Nevertheless, the more so-called sprains of the wrist are subjected to critical roentgenological study, the greater is the number of true bony lesions which are found.

Causation.— The explanation of the greater liability to injury of the scaphoid in comparison with the other bones of the carpus may be found

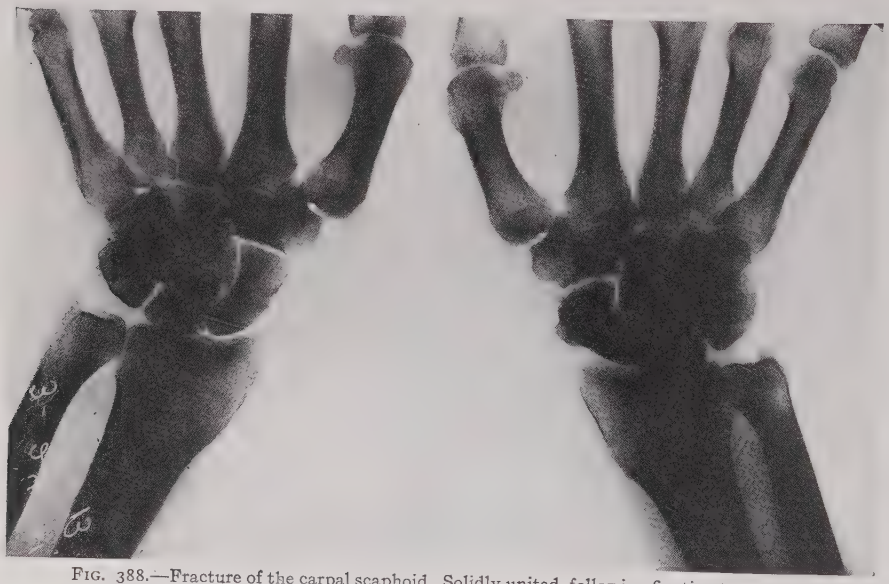


FIG. 388.—Fracture of the carpal scaphoid. Solidly united, following fixative treatment.

in its action as a buffer interposed between the os magnum and lower end of the radius to dissipate force transmitted to the forearm from the palm. It is fractured commonly as a result of indirect violence of the same type that causes fracture of the lower end of the radius, namely, a fall on the pronated, hyperextended hand. Usually it is the radius that suffers, but if this proves resistant, the scaphoid is fractured and not infrequently both are injured together.

Mechanism of Injury.—Several different types of fracture of the scaphoid may be recognized and a study of the morphology and physiology of the bone, with reference to the mechanism of injury, is of interest. The scaphoid has greater potentiality of individual motion than any of the carpal bones. Occupying the outer position in the first row of the carpus, its distal portion also enters into the formation of the second row. The radio-carpal joint cavity is prolonged downward from the radial styloid along the outer surface of the scaphoid, forming a pocket

which permits a gliding motion of the bones with and independent of the movements of the carpus. It is comparatively free from ligamentous attachments, being connected with the semilunar and os magnum by interosseous ligaments, but not similarly united to the trapezium and trapezoid. The two latter bones surmount the scaphoid and support the thumb and index fingers, the whole comprising the radial half of the proximal carpal arch.

When the hand is radially deflected, the radio-carpal pocket is closed and the ulnar half of the bone is pinned between the radius and os magnum; in radial deviation, too, the bone tilts in an antero-posterior direction so that the tuberosity comes forward. The long axis of the bone thereby comes to be more nearly at right angles to the long axis of the forearm. When the wrist is dorsi-flexed and at the same time radially deviated, the tilting goes a step further. The body of the bone in this position is clasped by the radius and the os magnum, leaving the tuberosity and the radial half of the bone free and unsupported. A fall on the hand acts by snapping the bone across at the junction of its fixed and unsupported parts and the radial half of the bone passes dorsally, in the event of displacement.

Varieties of Fracture.— The great majority of fractures of the scaphoid are breaks through the middle of the bones, the so-called "snapped waist" type of fracture, and are the result of falls or back-fire injuries, the wrist being in a position of hyperextension and radial deflection when the trauma is exerted. Forcible ulnar deviation of the hand accounts for a second variety of scaphoid fracture. The traction thus exerted through the radio-carpal ligament avulses the tuberosity, the so-called "avulsed tuberosity" type of fracture. Still a third mechanism of fracture, although rare, is by hyperflexion of the wrist, the bone being again broken near its middle. Compression fracture by crushing of the bone against the radial styloid has also been described, but it is doubtful if this mechanism really occurs.

Diagnosis.— The history of severe trauma is important from the standpoint of diagnosis, especially in the old, unrecognized cases, and from a consideration of its particular nature it is often possible to predict the exact type of fracture. Swelling of the wrist presenting definite characteristics is a marked and early feature. In a sprain of the wrist the swelling is generalized and diffuse, but in fracture of the scaphoid the swelling is localized as a soft œdema without ecchymosis in the region of the "anatomist's snuff-box," obliterating the outline of the tendons bounding the space. Gentle examination discloses a point of acute local tenderness in the base of the space, distal to the radial styloid and proximal to the base of the first metacarpal. It is well to note, particularly in the late cases, that pressure here is normally painful because of the situation of the radial nerve, but a mistake is not likely on this account if compari-

son be made with the uninjured side and if it be remembered that continuance of the pressure quickly causes analgesia under normal conditions. Movements of the wrist are limited and painful, particularly dorsi-flexion and radial deviation. Movements of the thumb are also painful, and a thrust on the thumb and index finger in the proximal direction causes pain in the region of the scaphoid.

Radioscopy.—Roentgenological examination should always be employed, and with proper attention to certain details of technic may be depended upon to reveal fracture if present. Codman and Chase [6] recommend that views of both hands be taken, the hands being placed palm down-

FIG. 389.—Long plaster cock-up splint used in fractures of the scaphoid. Note that the hand is in the position of optimum function.

ward, ulnarly deflected and the thumbs together. Stereoscopic plates are of great value. Confusion may arise in the interpretation of the plates from the occasional presence of a bipartite or partially cleft scaphoid, which according to Pfitzner, has an occurrence normally of one-half of one per cent. The history of injury, the absence of comminution or fracture irregularity, and the fact that when present the condition is usually bilateral, help in the differentiation.

Treatment.—The carpal scaphoid has hitherto possessed a well merited reputation for the frequency of non-union after fracture, but we can fully endorse the method of treatment advised by Todd [7] as likely to effect union in the great majority of cases. The hand and wrist are immobilized in the position of grasp: that is, with the wrist dorsi-flexed, the fingers moderately flexed, and the thumb lying beneath the index finger in the position of opposition (see Fig. 389), upon a long, moulded plaster cock-up splint. The finger motions must be abolished to prevent movement of the flexor tendons across the carpus, and fixation of the thumb is absolutely essential to prevent motion at the seat of fracture.

[6] Codman and Chase, *Annals of Surg.*, March, 1905.
[7] Todd, *ibid.*

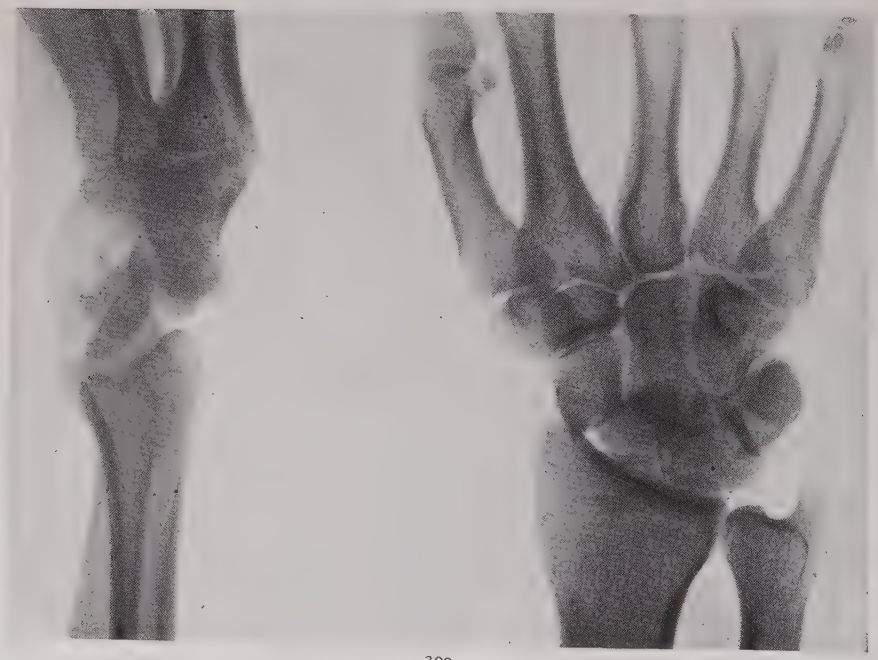
When there is displacement and limitation of wrist dorsi-flexion, reduction may be carried out by making strong traction on the sharply flexed wrist, direct pressure being brought to bear at the same time on the displaced fragment. In the event of failure to reduce, the offending fragment must be removed by operation forthwith, as it mechanically interferes with function and sets up a reactionary arthritis which is exceedingly difficult to remedy.

Massage of the limb as it lies in the splint should be employed after the lapse of several days. A short cock-up splint may be used at the end of three weeks and a moulded leather wristlet or broad wrist strap at the end of four weeks. This may be gradually discontinued as function returns. Massage, mobilization, both active and passive, with contrast bathing and other forms of physiotherapy are continued. A fracture of the scaphoid means a period of at least three months' disability in a working man.

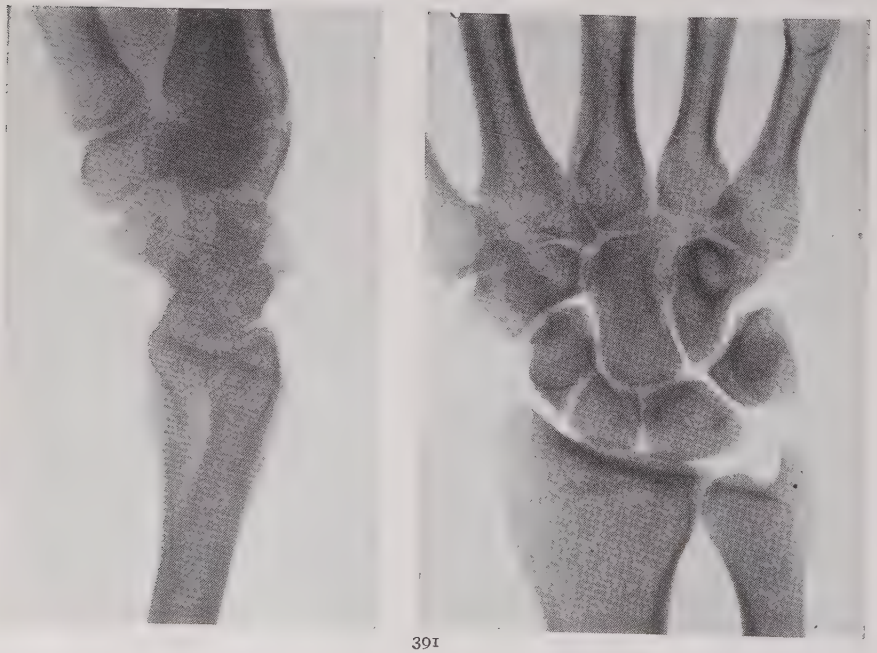
Non-union.— In the fact that out of thirty cases reported by Codman and Chase [8] only those cases showed union, three in all, which had been immobilized for a reasonable period of time, is to be found the answer to the query of why fractures of the carpal scaphoid so frequently fail to unite. We have been struck by the very definite atrophy of the distal fragment which develops shortly after injury, and this suggests that the main source of blood supply has been affected by the fracture, the normal density of the fragment returning as union proceeds. Contributory reasons are to be found in the fact that the fragments are bathed in synovial fluid, which has an inimical effect on bone production.

Operative Excision.— It is doubtless true, however, that non-union will be met with in spite of the plan of treatment outlined above, and if at the end of three months union has not taken place and pain on motion still persists, operative removal of the offending fragment should be undertaken before a secondary arthritis, directly attributable to the non-union, and at whose door the pain and weakness of grasp are to be laid, has been allowed to establish itself. In some cases removal of the entire scaphoid may be necessary. Exposure is best obtained through an incision on the dorsum of the wrist, passing to the ulnar side of the extensor longus pollicis tendon. We wish particularly to give warning that occasionally at operation, in spite of well-marked roentgenological evidence of non-union, the fragments will be found solidly connected by fibrous union with complete obliteration of the fracture line. This has happened in two of the authors' cases, and although excision of the proximal half of the bone was proceeded with, it is doubtful if operation will improve such cases, and is an argument for conservatism. The mere fact that

[8] Codman and Chase, *Annals of Surg.*, March, 1905.



390



391

FIGS. 390 and 391.—Fracture of the scaphoid and dislocation of the semilunar with retrolunar displacement of the os magnum. (390) Before reduction. (391) Following reduction by direct traction and flexion of wrist. (Fracture Service, M. G. H.)

roentgenoscopy reveals a persistent unhealed fracture line does not warrant operative removal. Such findings are not uncommon in cases which clinically show perfect function.

B. DISLOCATION OF THE SEMILUNAR BONE

All reports agree that dislocation of the carpal semilunar bone is not as uncommon as previously supposed. It certainly occurs with greater frequency than any other dislocation of the carpus. It may occur alone or in combination with other carpal lesions, particularly fracture or dislocation of the scaphoid, and less frequently fracture of the os magnum.

Mechanism.— Simple luxation uncomplicated by fracture takes place practically always in the anterior direction. The injury is commonly produced by a fall on the hyperextended palm or a blow on the dorsum of the wrist. In the movement of hyperextension the distal row of the carpus passes backward, while anteriorly the space between the os magnum and radius is widened. The posterior wedge-shaped extremity of the semilunar is compressed between the os magnum and the articular surface of the radius, and in this position with force applied to the palm the bone is squeezed forward out of its socket as a pea from its pod. The degree of displacement depends upon the amount of ligamentous injury. The radio-lunar ligament usually remains intact and causes the bone to rotate so that it looks anteriorly instead of distally. In some cases the os magnum slips backwards, its displacement being limited by the intact posterior ligament. Occasionally this forms the predominant part of the displacement, the semilunar remaining more or less in contact with the articular surface of the radius, and this has led to the designation of the injury by some as dislocation of the os magnum or retro-lunar displacement. This type of dislocation applies particularly to dislocation of the semilunar associated with fracture of the scaphoid. Since the latter bone occupies a place in both proximal and distal rows of the carpus this injury should properly be regarded as an intracarpal dislocation, the distal upon the proximal row.

Diagnosis.— The clinical signs are pain, disability and particularly stiffness of the wrist and fingers. The pain is often excessive, due to direct pressure and irritation of the median nerve by the displaced bone. The wrist is swollen and there is an unusual anterior prominence under the tendons of the wrist. The fingers are usually flexed and cannot be completely extended, nor can the wrist be dorsi-flexed. The roentgenogram reveals the luxation clearly in the lateral view, but is apt to be deceptive in the antero-posterior view. It may be easily overlooked unless special attention is paid to the carpus. Many such injuries have escaped diagnosis until weeks or months after the original accident, when the persistence of pain and disability has led to fresh examination.

Reduction.—When seen within a week of the injury, reduction should be attempted with the Thomas wrench. Stern [9] reports four successful results in five cases by this method. Under general anæsthesia the wrench

392

393

FIGS. 392 and 393.—Old unreduced fracture of the scaphoid and dislocation of the semilunar with retro-lunar displacement of the os magnum. (392) Antero-posterior view. (393) Lateral view. (Fracture Service, M. G. H.)

is applied with the distal blade on the anterior surface of the wrist, impinging against the displaced bone while the proximal blade rests on the dorsum of the lower end of the radius, the handle being directed dor-

[9] W. G. Stern, *Journ. Amer. Med. Asso.*, November 20, 1920, p. 1389.

sally (see Fig. 394). Leverage is now applied to the wrench, forcing the hand and wrist into hyperextension as far as they will go, thus opening up the semilunar bed between the radius and os magnum. Then while maintaining the pressure of the wrench against the semilunar, the hand and wrist are forcibly flexed in order to open up the posterior portion of the semilunar socket and cause replacement. The wrist should be immobilized immediately in the flexed position by the application of anterior and posterior moulded plaster splints leaving the fingers and thumb free. Massage and mobilization of the wrist may be begun at

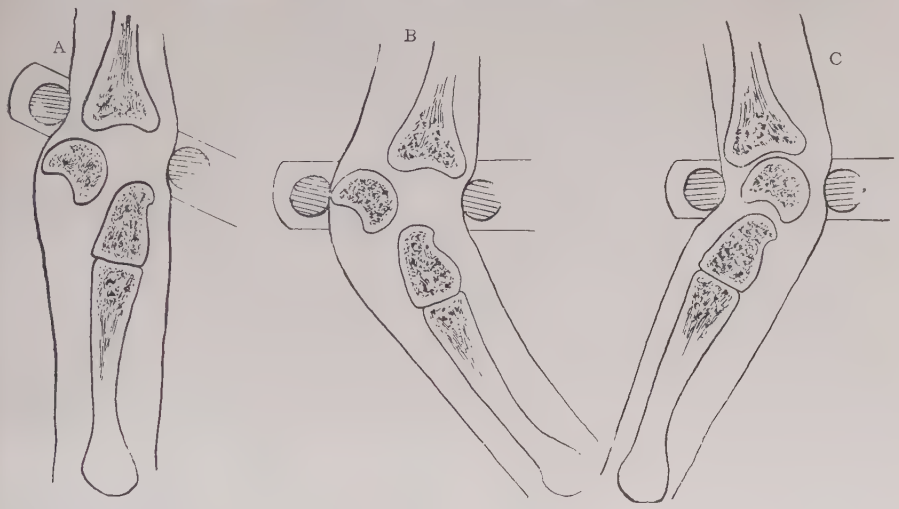


FIG. 394.—Reduction of dislocation of semilunar with Thomas wrench. (A) The wrench is applied with the distal blade on the palmar surface resting against the displaced bone. (B) Leverage is brought to bear against the bone while at the same time the wrist is dorsi-flexed as far as possible. (C) While continuing the pressure with the wrench the hand is now palmar flexed over the distal blade, this completing the replacement.

the end of three days, avoiding movements of hyperextension. The splints may be discontinued at the end of two weeks.

Excision.— In cases seen after the lapse of ten days, successful reduction can scarcely be expected. On the other hand, functional recovery is impossible with the persistence of the displacement, as the bone mechanically interferes with the use of the flexor tendons and frequently causes pressure upon the median nerve. Under these circumstances, open reduction, or in case this fails, excision, is to be advised. The approach is through an anterior incision to the inner side of the tendon of the brachioradialis. The radial artery and nerve with the superficial flexors are retracted to the ulnar side and the pronator quadratus exposed. The anterior radio-carpal ligament is then incised and the dislocated semilunar comes readily into view. The results of excision of the semilunar bone when performed early have been excellent, practically complete restoration of function, except for the very heaviest work, having been obtained.

C. OTHER FRACTURES AND DISLOCATIONS OF THE CARPAL BONES

Fractures.—Fracture involvement of a single bone of the carpus other than the scaphoid occurs so infrequently as scarcely to constitute a clinical entity. The semilunar is occasionally the seat of a compression fracture which may or may not be accompanied by dislocation forward of the bone. The os magnum is fractured next in frequency, usually from the effects of direct violence on the dorsum of the wrist or from a fall on the end of the middle finger. The latter injury may be accompanied by a certain amount of displacement of the fragments. Cases are on record of fracture of each of the remaining carpal bones; usually either a compression injury with crushing of the bone or a fissured fracture with little tendency to displacement. Treatment of these injuries is along similar lines to that of fracture of the scaphoid. When displacement exists, reduction by manipulation and direct pressure is to be attempted. In the event of irreducible displacement causing mechanical interference with function, excision of the displaced fragment is to be advised. In fresh injuries immobilization on a long plaster cock-up splint, for a period of three to four weeks, is necessary to obtain union.

Dislocations.—Dislocation of a single bone of the carpus, apart from the semilunar, without other associated injury of the carpus is of rare occurrence. It occasionally happens that the scaphoid is luxated posteriorly from forced hyperflexion of the wrist. In the movement of flexion the two rows of the carpus have a tendency to pass in opposite directions, the proximal row dorsally and the distal row ventrally, the first stage of an intercarpal dislocation. The scaphoid is insecurely supported posteriorly by the tendons of the radial extensors, and with such a mechanism may be displaced backward from its articulations. More often, however, as a result of the fact that the scaphoid enters into the formation of both rows of the carpus, a movement of the two ends of the bone in opposite directions causes fracture at the waist, and this is a frequent complication of dislocation of the semilunar, the proximal fragment being displaced forward with the semilunar or occasionally in divergent directions.

Luxation of the os magnum usually means a displacement of the head of the bone from its articulation with the scaphoid and semilunar, which may at the same time suffer fracture. The head of the bone passes backward and is palpable opposite the base of the third metacarpal, when the hand is flexed. There are local pain and tenderness and antero-posterior thickening with limitation of the movements of the radio-carpal joint. Direct pressure over the displaced bone, along with strong traction, may effect reduction, the wrist being flexed and extended the while.

Treatment.—In the case of extensive traumatic lesions involving the carpal bones the treatment should be directed toward immobilizing the

wrist and hand in the position of optimum function; that is, in the position of grasp. A firmly ankylosed wrist with flexible fingers and thumb occasions but slight disability when the wrist is in the most useful position. In the late cases with weakness of grasp and painful and limited movement one must choose between an operation to provide a greater range of mobility, such as excision of the proximal row or of both rows of the carpus, or an operation to cause ankylosis. In most cases the latter condition is preferable.

4. CARPO-METACARPAL DISLOCATIONS

Dorsal Luxation.—Luxation of any of the carpo-metacarpal joints, but more frequently that of the thumb, may result from forcible flexion or extension of the metacarpals upon the carpus. Such accidents are not common and the dorsal variety resulting from flexion is the more usual. Reduction by traction and direct pressure on the displaced bone is usually not difficult. There is a definite tendency to recurrence of the deformity without proper retention, and this is best accomplished by the application of a traction splint (Figs. 404, 405), with continuous elastic traction to the affected finger. This should be combined with a local dressing consisting of a felt or cotton pad with adhesive strapping applied in such a manner as to exert direct pressure over the seat of the displacement.

Incomplete Luxation.—Incomplete dorsal luxation of the carpo-metacarpal joint of the thumb is invested with considerable interest because incomplete reduction or recurrence of the displacement results in weakness and poor function of the thumb. This condition may develop acutely as the result of trauma, in which case reduction followed by the application of continuous traction with the thumb in the position of opposition (Fig. 396) is indicated. In certain individuals with atonic muscles and relaxed joints, however, what apparently amounts to a condition of chronic subluxation may develop without acute trauma. Pain on movement and weakness are the usual symptoms, and relief is promptly obtained by the wearing of a leather strap encircling the wrist at the level of the basal joint of the thumb, with a strap passing over the base of the thumb to hold it in place (Fig. 373).

In cases of recurrent traumatic dislocation of the carpo-metacarpal joint of the thumb not relieved by the use of the wrist strap above mentioned, it may be necessary to perform the operation of erasion of the cartilage of the joint with the view to obtaining ankylosis in the position of apposition, which is the optimum position for function. With the basal joint stiffened in this position grasping movements with the fingers are possible and function of the hand is excellent.

5. COMPOUND INJURIES IN THE REGION OF THE WRIST

Treatment of Infection.— The immediate treatment of compound injuries of the wrist is operative débridement to prevent wound infection. When

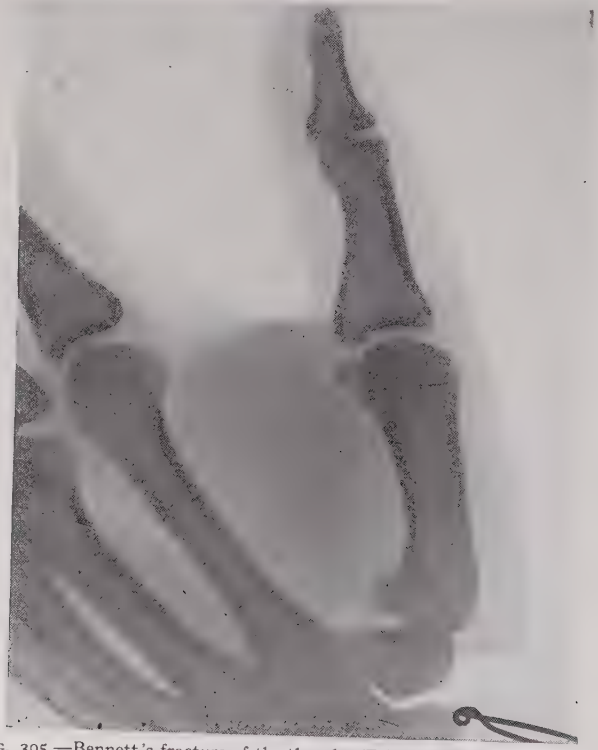


FIG. 395.—Bennett's fracture of the thumb. (Edinburgh Royal Infirmary.)

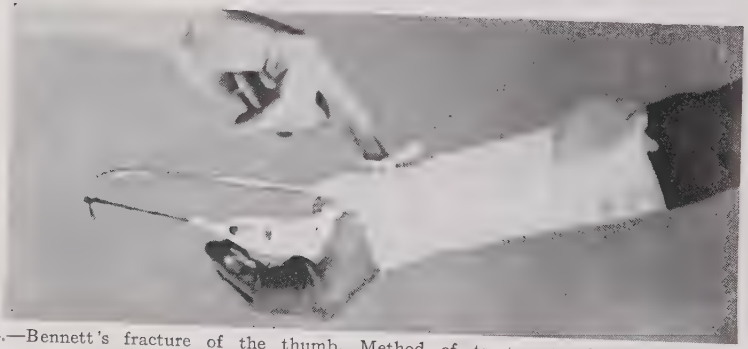


FIG. 396.—Bennett's fracture of the thumb. Method of treatment with traction. Thumb in optimum position.

sepsis develops, however, the most important feature of the treatment, in addition to the provision of drainage, is an appreciation of the fact that whether ankylosis is likely to supervene or not, the best guarantee of eventual maximum function is the splinting of the wrist in the

position of thirty degrees dorsi-flexion. In these cases also, the addition of a banjo finger traction attachment (Figs. 426 to 430) to the cock-up splint is of great value in separating the inflamed joint surfaces and providing the rest which allays pain and of itself limits sepsis.

Treatment of Deformity.—If the wrist has been allowed to become stiff in an attitude of flexion its position must be altered. When a reasonable time has been allowed to elapse to lessen the probability of lighting up a latent infection, the position may be gradually corrected by altering the angle of a long metal cock-up splint from day to day, bent at first to conform to the angle of deformity. Contrast baths, massage and active and resistive exercises for the fingers and wrist are also necessary. The reaction set up by this method is minimal and the final results are more

FIG. 397 (A, B).—Fracture of the shaft of the metacarpal. (A) Illustrating the common posterior angular deformity. (B) Dropping of the knuckle of the middle finger.

satisfactory than after a single manipulation. When there is true bony union, however, correction by osteotomy is required.

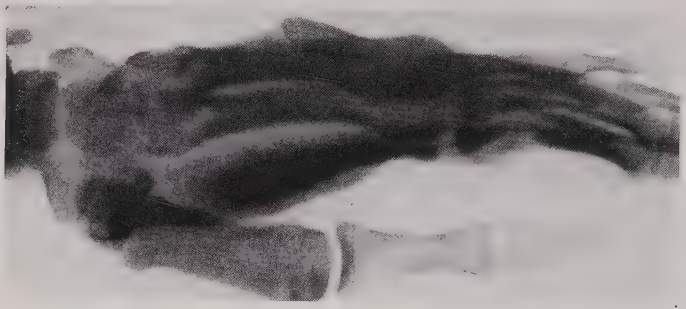
III. INJURIES OF THE METACARPALS AND FINGERS

1. FRACTURE OF THE METACARPAL BONES

a. BENNETT'S FRACTURE OF THE BASE OF THE FIRST METACARPAL BONE

Displacement and Diagnosis.—This fracture, the old time "stave of the thumb," was first described by Bennett, of Dublin. It consists of an "oblique fracture through the base of the bone, detaching the greater part of the articular facet with that piece of the bone supporting it which projects into the palm." (Fig. 395.) The injury usually results from a fall or a blow directly on the point of the thumb in its long axis or from a blow with the clinched fist. The proximal end of the distal fragment slips dorsally, forming a prominence just below the carpo-metacarpal joint. There are swelling and tenderness at the base of the thumb and movements of the latter are painful and accompanied by crepitus. The recognition of the injury is important, as prolonged impairment of function from inability to fully abduct and to carry out the finer movements of the thumb results from failure to reduce the deformity.

Treatment.—Reduction should be performed under ether or gas anæsthesia, but the deformity tends to recur without proper retention. The latter may be prevented by the use of continuous elastic traction to



398

399

FIGS. 398 and 399.—Fracture of the metacarpal. (398) Lateral view showing marked posterior angulation. (399) Callus formation and shortening shown in antero-posterior view. (Fracture Service, M. G. H.)

the thumb, employing a plaster wristlet in which is incorporated a small wire frame to maintain the traction (Fig. 396). We believe there is definite advantage in placing the thumb in the position of opposition, the position of optimum function, instead of in the position of hyperextension as so commonly advised.

b. FRACTURE OF THE METACARPAL SHAFT

Pathology.—Fracture of the shaft of one or more of the metacarpal bones is a fairly common injury. It may result from violence of a direct crushing nature, and then the fracture, either single or multiple, with or

FIG. 400.—Oblique fracture of the third metacarpal from indirect violence. Force transmitted through the middle finger. (Edinburgh Royal Infirmary.)

without comminution, is usually accompanied by but little displacement. The typical injury, however, is an oblique fracture due to indirect violence, such as a blow with the clinched fist, the force being received on the knuckle and tending to increase the natural dorsal convexity of the bone beyond its limits of elasticity. Such fractures are accompanied by considerable displacement with sinking of the metacarpal head into the palm and marked dorsal bowing. The integrity of the longitudinal and transverse arches

is impaired and an important disabling factor, in case the deformity is not corrected, is that the lumbricales and interossei act under a mechanical disadvantage in fixing the metacarpo-phalangeal joint. Fixation of this joint is necessary when making an effort to grasp, in order to give a fixed point for the long flexor tendon in flexing the terminal phalanges.

The diagnosis is usually quite apparent from the swelling, tenderness, and deformity on the dorsum of the hand and the depression of the knuckle. The characteristic deformity is clearly revealed in the lateral roentgenogram.

Treatment.—The treatment depends upon the presence or absence of displacement. In the cases without displacement the most convenient

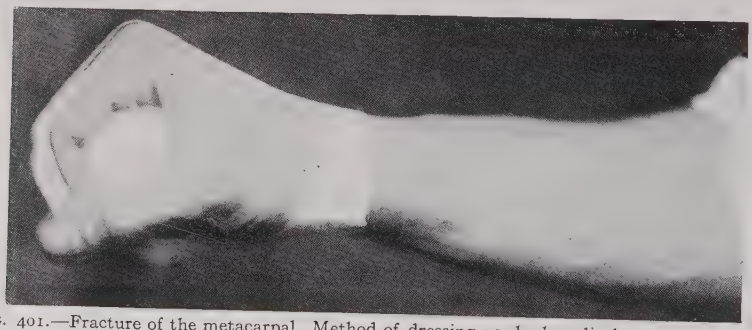
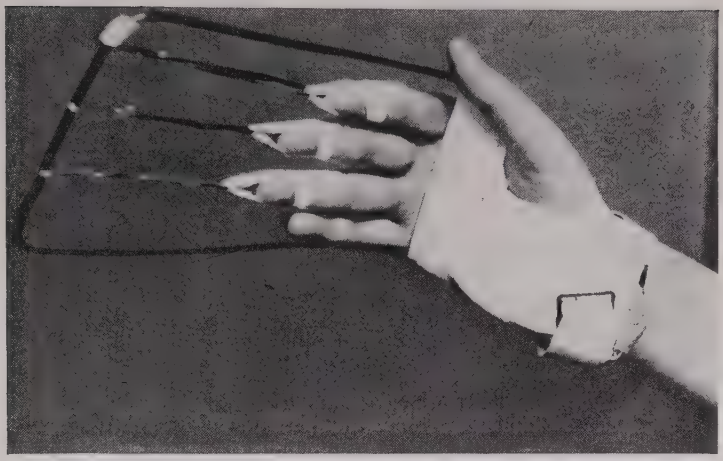


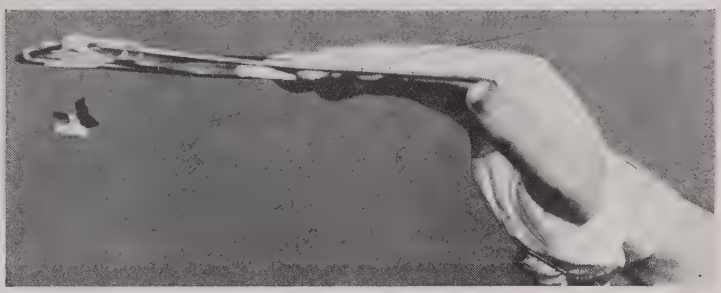
FIG. 401.—Fracture of the metacarpal. Method of dressing used when displacement is absent.

method is to flex the fingers over a firm, rounded pad, such as a roller bandage wrapped in wool, which fills the palm. This preserves the arched arrangement of the hand and immobilizes the finger joints (Fig. 401). The dressing should be worn for ten days and union is usually firm in three weeks.

Displaced Fractures.—In fractures with displacement the use of continuous traction is necessary to correct deformity. A type of traction splint which serves the purpose well is shown in figures 402, 403. It consists of a plaster casing of the forearm with palmar support, in which is incorporated a rectangular frame of iron wire, to which the rubber tubing or elastic bands which take the extension from the digits is attached. The splint may be modified according to the number of fingers involved (Figs. 404, 405, 426, 427). The amount of traction required is not very great, but it should be maintained until callus has been thrown out, usually a matter of ten to fourteen days. The palmar portion of the splint should be moulded into the arches of the hand in order to preserve their contour, and cut out freely about the thenar eminence to allow movement of the thumb.

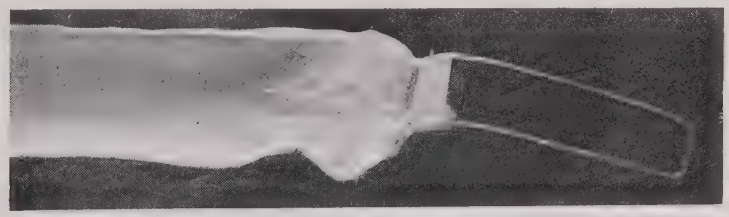


402



403

FIGS. 402 and 403.—Multiple fractures of the metacarpals. Small banjo splint used for applying traction. Splint is made from plaster of Paris in which wire frame is incorporated. Traction is obtained by elastic bands. Note that the wrist is dorsally flexed and the metacarpo-phalangeal joints are flexed. (402) Anterior view. (403) Lateral view.



404

405

FIGS. 404 and 405.—Fracture of the metacarpal. Method of applying traction. (404) Small moulded plaster splint in which wire frame has been incorporated. (405) Splint applied. Traction secured by rubber elastic band.

FIG. 406.—Fracture of the third, fourth and fifth metacarpals in a child. Note also the fracture of the epiphysis of the proximal phalanx, index finger.

FIG. 407.—Fracture of the base of the fifth metacarpal. "Stave fracture." (Edinburgh Royal Infirmary.)

c. OTHER FRACTURES OF THE METACARPAL BONES

Fracture through the bases of the metacarpals may result from direct violence. Such injuries show little or no displacement and the results are good from simple protective splinting alone. Fracture of the head of the bone, with involvement of the articular surface, is also occasionally seen. Separation of the joint surfaces is advisable during the process of healing

FIG. 408.—Fracture of the base of the second metacarpal. (Edinburgh Royal Infirmary.)

and may be obtained with one of the traction splints previously mentioned. Without gross change in the articular contour, good function may be expected.

2. DISLOCATION OF THE METACARPO-PHALANGEAL JOINTS

The dislocation most frequently encountered in this region is dorsal luxation of the proximal phalanx of the thumb. Dislocation of the metacarpo-phalangeal joint of the little finger occurs next in frequency, while luxation of the corresponding joints of the second, third and fourth fingers is a rare happening. Dorsal luxation of the thumb is a classical

condition and it alone will be described, the main features of dislocation of the other fingers resembling it, except that in general, reduction is less difficult because of the greater simplicity in the muscular arrangement. Reduction is to be obtained in an identical manner as in the case of the thumb.

a. DORSAL LUXATION OF THE PROXIMAL PHALANX OF THE THUMB

Causation.— Dislocation of the metacarpo-phalangeal joint of the thumb occurs practically always as the result of forcible hyperextension of the proximal phalanx, the anterior capsular ligament being torn and the base of the bone being displaced dorsally. To understand why reduction often

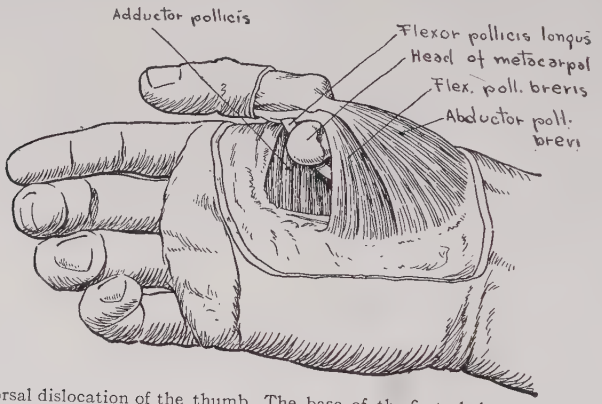


FIG. 409.—Dorsal dislocation of the thumb. The base of the first phalanx is dislocated to the dorsal side of the head of the first metacarpal. Capsule is torn on the flexor surface, allowing the metacarpal head to protrude; the long flexor tendon and the tendon of the flexor pollicis brevis slipping over and engaging about the neck. (After Helferich.)

proves so difficult, it is necessary to bear in mind the anatomy of the structures involved.

Anatomy.— The head of the metacarpal is much enlarged in comparison with its shaft. The structures reinforcing the joint consist of an anterior capsular thickening, often partly cartilaginous, and two lateral ligaments. Inserting into the outer side of the base of the phalanx and blending with the external lateral ligament is the common tendon of the abductor and outer head of the flexor pollicis muscles, containing a well-developed sesamoid bone. Inserting in a similar manner, but on the inner side of the base of the proximal phalanx and also containing a sesamoid are the tendons of the adductor obliquus, transversus pollicis, and inner head of the flexor pollicis. The tendon of the flexor longus pollicis lies on the anterior surface of the joint, passing to the terminal phalanx.

Pathology.— When the joint is dislocated, the anterior and lateral ligaments are torn at their proximal attachment and the base of the phalanx passes dorsally, carrying its ligaments with it and coming to rest behind

the enlarged metacarpal head, where it is firmly held by the tension of the lateral tendons. The head of the metacarpal projects forward between the two heads of the flexor brevis and may be readily palpated by reason of its superficial position in the thenar eminence. The capsular ligament

FIG. 410. Posterior dislocation of the proximal phalanx of the thumb associated with small chip fracture of the articular surface. (Edinburgh Royal Infirmary.)

is stretched across the back of the metacarpal neck under tension and interferes with reduction. The tendon of the flexor longus pollicis usually slips to the inner side.

Reduction.— Reduction by traction alone is impossible and recourse must be had to indirect measures. The surgeon grasps the metacarpal with the right hand and with this as a fixed point the deformity is first increased by hyperextending the proximal phalanx with the left hand.

Then, while maintaining the latter position, strong pressure is exerted with the right thumb against the base of the phalanx to lever it over the head of the metacarpal (Fig. 411). Flexion of the phalanx completes and maintains the reduction. Difficulty in effecting reduction is due to the interposition of the volar accessory ligament and sesamoids between the phalanx and metacarpal. When attempts at closed reduction fail, the volar accessory ligament should be divided longitudinally, so separating the sesamoid bones and allowing the passage of the head of

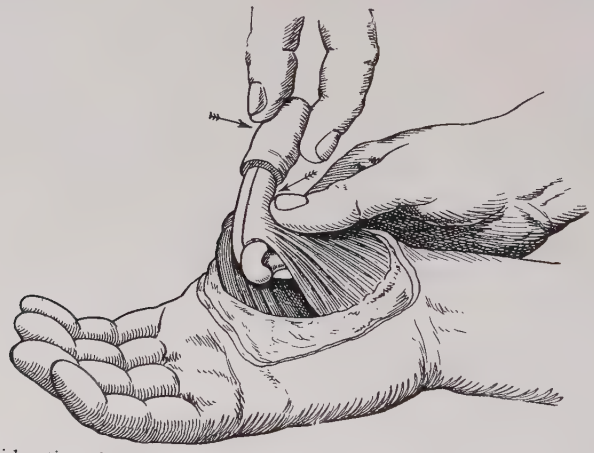


FIG. 411.—Dislocation of the thumb. Correct method of reduction. The deformity is increased by hyperextension of the thumb, and in this position, direct pressure is exerted against the base of the phalanx. When the articular surfaces are in contact, the thumb is flexed and reduction occurs. (After Helferich.)

the metacarpal between them. This may be done through a puncture made by a tenotomy knife on the dorsal aspect of the joint.

Fixation.— In this variety, as well as in the rarer forward and lateral dislocations, recurrence is prone to occur if a reasonable time is not given for repair to take place, or if certain movements are allowed too early, *e.g.*, extension in the case of a backward dislocation. The best means of retention is by the application of elastic traction, utilizing for the purpose a light plaster casing of the hand with a wire frame incorporated in it, enclosing the thumb and extending distally to support the traction (Fig. 396). By this means the joint surfaces are separated, recurrence is prevented and healing occurs with the structures in position to allow motion. The older method of applying a moulded aluminum or tin gutter splint to the dorsum of the thumb maintained the correction well enough, but frequently ended in stiffness.

An incomplete form of dorsal dislocation has been described in which the base of the phalanx rests on the posterior angle of the articular surface of the metacarpal. Reduction is easily obtained by traction.

3. INTERPHALANGEAL DISLOCATIONS

Either the ungual or second phalanges may be dislocated forward, backward or laterally. The injury is usually the result of a blow received on the tip of the finger with hyperextension of the phalanx, and for this reason the dorsal type is more common. The anterior edge of the articular base of the phalanx may be chipped off, and in this type retention may be difficult and necessitate continuous elastic traction (Figs. 421-423).

Reduction.—In the uncomplicated dislocations reduction is readily accomplished by direct traction, although if difficulty is experienced, re-

FIG. 412.—Fracture dislocation of the base of second phalanx, showing reduction by traction.

course should be had to the manœuvres used in the case of dislocation of the proximal phalanx of the thumb, that is, of first increasing the deformity before attempting replacement. Following reduction, a simple, straight splint should be applied and motion started at once, its range being increased daily. Forcible passive movements should be avoided.

4. FRACTURE OF THE PHALANGES

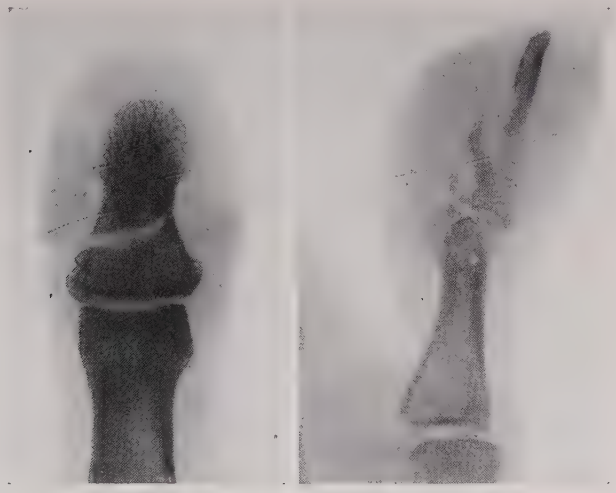
Fracture of a phalanx is a common injury, the proximal phalanx being most frequently affected, and may result from direct or indirect violence. Not infrequently the fracture is compound, and in machinery accidents with extensive laceration, may necessitate amputation. All types of fracture may be encountered, ranging from a simple transverse break to severe comminution. Mention has already been made above of fracture complicating dislocation. Displacement may be present of an angular or overriding nature, or completely absent. The recognition of these fractures

FIG. 413.—Fracture of the proximal phalanx of the fourth finger by direct violence. (Fracture Service, M. G. H.)

FIG. 414.—Multiple fracture of the proximal phalanges from crushing injury. (Edinburgh Royal Infirmary.)

is usually not difficult, but the roentgenogram provides definite information regarding treatment.

Treatment.— The treatment depends upon the presence or absence of displacement. In the latter case, the application of a simple finger splint is all that is required, this being extended well down into the palm when the proximal phalanx is involved. In the fractures with displacement the deformity must be corrected, as otherwise it results in visible disfigurement and impairment of function. Manipulative reduction, followed by retentive splinting, may be the best course in certain cases, but usually a better method is to obtain gradual correction of the deformity by the



A B

FIG. 415.—Fracture of the distal phalanx of the thumb. (A) Antero-posterior view. (B) Lateral view.

use of continuous elastic traction with such an apparatus as is portrayed in figures 420–422. By this means, callus formation is reduced to a minimum and joint function preserved better than by immobilization alone. In the convalescent stage, warm baths and massage are of value.

Attention has recently been drawn to the comminuted fractures of the terminal phalanx of the thumb by Maddren,[10] who has found that such injuries are apt to result in surprisingly long disability periods. This is apparently due to the slow resolution of the hæmatoma in the pulp of the finger and he advises prompt incision to evacuate the blood and avoid this difficulty.

5. "BASEBALL FINGER" (DROP OR MALLET FINGER)

Pathology.— This term is applied to a persistent flexion deformity of the terminal phalanx which results from violence applied to the end of the extended digit, a frequent baseball injury. The phalanx is forcibly

[10] R. F. Maddren, *J. A. M. A.*, 75, 1198, October 30, 1920.

flexed against the resistance of the extensor tendon, with the result that the insertion of the latter is ruptured, or, which is more frequent, the bit of bone to which it is attached is avulsed. The bony character of the injury is clearly shown by a lateral roentgenogram (Fig. 417). When

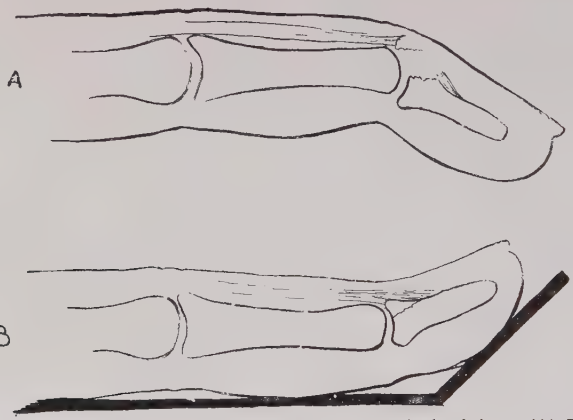


Fig. 416 (A, B).—Mallet finger. Diagrammatic representation of the injury. (A) Typical deformity. (B) Reduction by hyperextension of distal phalanx.

the patient is seen, the ungual phalanx is markedly flexed and cannot be extended voluntarily, although passively this is possible.

Treatment.— The treatment of this condition has usually consisted in either an attempt at operative repair, simple straight splinting, or nothing

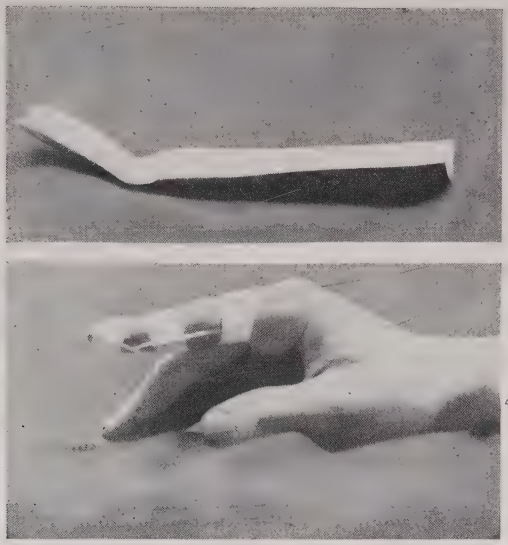
Fig. 417.—Roentgenogram of mallet finger showing the bony injury which is frequently present.

at all. Since Dr. R. B. Osgood first called our attention to this condition, we have been using his method of splinting the finger with hyperextension of the distal phalanx, and have been struck with the uniformly successful results, even in old cases. It is apparently necessary to continue the use of the splint, which is made of aluminum or tin (Figs. 418, 419), for four to six weeks. However, as full use of the hand and remaining fingers is permitted, this represents but a slight inconvenience.

6. COMPOUND INJURIES OF THE FINGERS AND THUMB

Functional Value.— Fractures of the phalanges and dislocations of the fingers and thumb are not infrequently compound, and painstaking treatment is necessary if the digit is to be saved and its function preserved.

From the functional viewpoint, it is important to bear in mind that on each hand we have four fingers, but only one thumb. A stiff, useless finger may of itself constitute such an annoyance that the functional value of the hand is increased by its removal, but the same is never true of the thumb. The ability to grasp requires counter-pressure for the fingers, and only the thumb can provide this. Even when the latter is completely ankylosed almost normal function is possible if the position



418

419

FIGS. 418 and 419.—Treatment of mallet finger. (418) Small aluminum finger splint. (419) Splint applied.

is that of optimum function, that is, with the thumb in the position of opposition (Fig. 334), directly beneath the index finger. When stiffness of the fingers is to be expected, they should be splinted in partial flexion.

Débridement and Splinting.— However, ankylosis is by no means a necessary result of a compound injury, particularly if infection is avoided by early and careful débridement. If tendons have been lacerated they should be repaired at the same time, or if this is impossible, the wound should be closed by primary suture, with a view to tendon grafting at a later period. In general, traction splints, as shown (Figs. 420-422), should be used for the correction of deformity. They provide ample facility for dressing the wound, even in the presence of suppuration, and at the same time maintain alignment. If, on account of the situation of the wound, an insufficient skin area is available for the application of the necessary adhesive traction strips, the extension may be secured by passing a silk suture through the nail margin, or when no other means is available, direct skeletal traction may be had by passing a stout steel needle through the terminal phalanx (Figs. 424, 425).

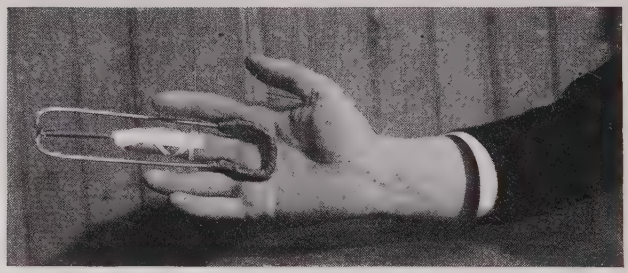
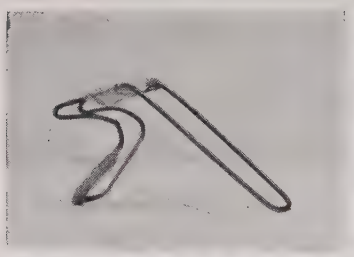
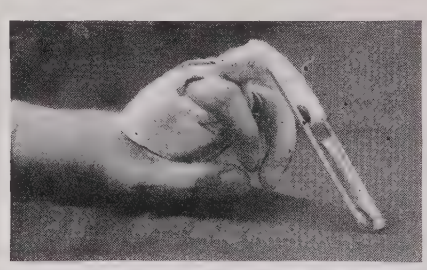


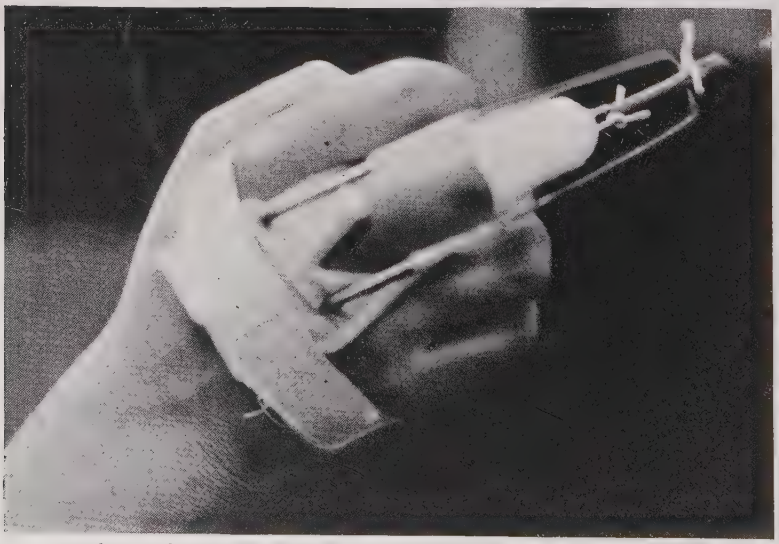
FIG. 420.—Small wire traction splint for fracture of the finger. The base of the splint is in the form of a saddle, the edges being padded with leather. This rides on the web of the fingers.

421





422

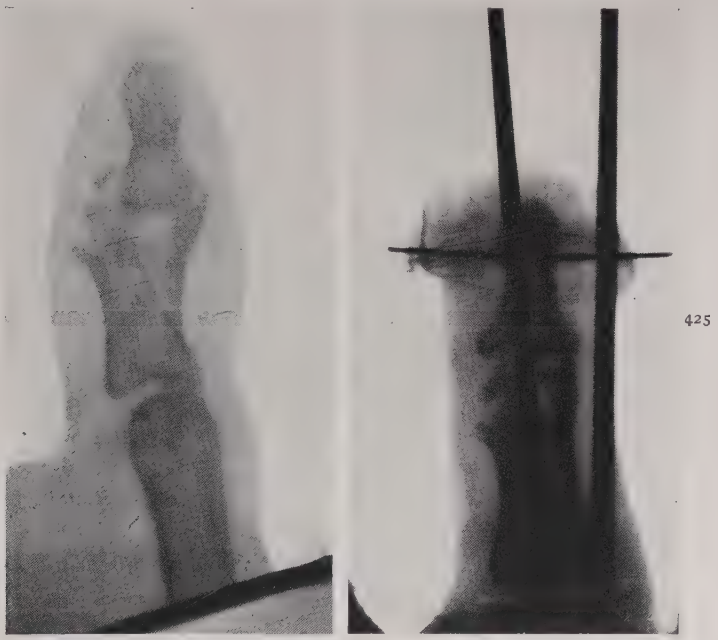


423

FIGS. 421, 422 and 423.—Small wire splint for finger traction in fracture of the phalanges. (421) Splint. (422) Splint applied. (423) Same splint, viewed posteriorly.

IV. THE TREATMENT OF STIFF HANDS

The Factors Causing Disability.—The features which stand out as being the most disabling after injury are joint-stiffness in bad functional position, incompletely reduced deformity, and the effacement of the mechanism on which the grasping power of the hand and the carrying out of its finer movements depend: in other words, the obliteration of the normal arches of the hand. Consideration of fractures in the region of the hand and wrist emphasizes the fact that in them, as in all articular and periarticular



FIGS. 424 and 425.—Compound fracture involving the articular surfaces of the second phalanx of the thumb. (424) Before reduction. (425) After reduction. Traction obtained by needle passed through proximal phalanx. (Fracture Service, M. G. H.)

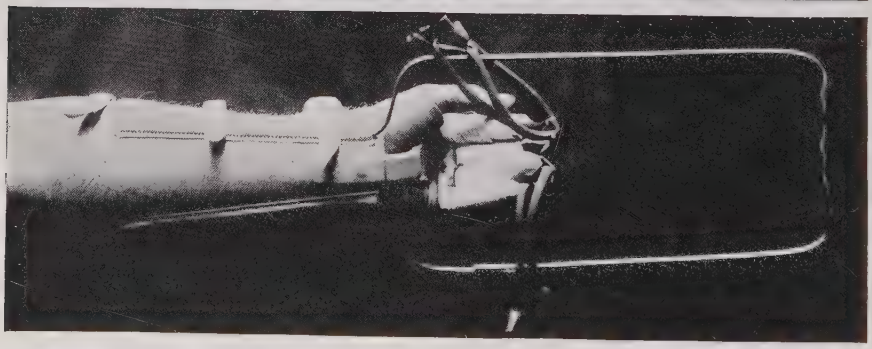
injuries, the effect of the injury upon the joint is of far greater importance than its effect upon the bone itself. Reduction of deformity and restoration of anatomic alignment should be the goal. The proper function of the joint demands this in regard to its line of action and the adequate power of the tendons acting on and over it; the lack of this is responsible for the pain and weakness of grasp which many cases present.

Apart from this, the state of affairs chiefly to be feared is to be found in its most severe degree in the partially or completely stiffened hand, the result commonly of prolonged immobilization and sepsis. The intra-articular adhesions and periarticular capsular thickening responsible for the joint stiffness, the binding down of tendons and tendon sheaths, the shiny, glazed and atrophied condition of a hand whose arches are lost,

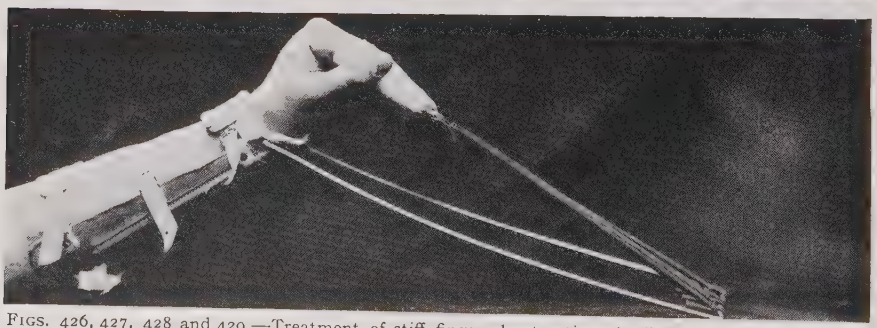
426

427

428



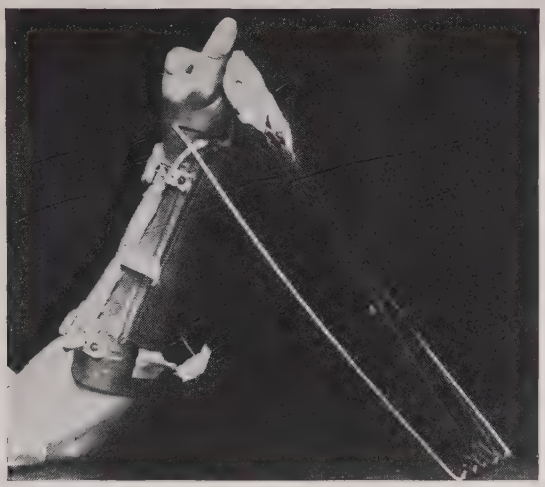
429



FIGS. 426, 427, 428 and 429.—Treatment of stiff fingers by traction. (426) Banjo splint applied. Anterior view. (427) Same, lateral view. (428) Elastic traction released to allow exercise of the fingers. (429) The wire frame of the banjo splint has been bent to an angle to cause flexion of the fingers.

whose thumb is in a position of adduction and extension, whose wrist is flexed and whose fingers are stiff, complete the picture of an extreme case. It is rare to see a hand stiffened in the functioning position, but if the surgeon, in cases where it is likely to happen, has the foresight to maintain the hand and wrist in the physiological position of grasp (Fig. 334), a surprising amount of function will remain in even the very worst cases of sepsis.

Treatment of Stiff Fingers.— The measures advisable for the correction of faulty attitudes of the wrist and thumb have been already indicated (see page 306). There still remains the question of stiffness of the fingers.



430.—Treatment of stiff fingers by traction. Later stage. The fingers can now be closed in the hand and the line of traction forms an acute angle with the wrist. (See text.)

Physiotherapy.— The less severe cases are relieved by alternate immersion in hot and cold water. The " contrast bathing " acts favorably upon the circulation and general tone of the hand; the masseur gently rubs the fingers while they are in the water, traction being exerted at the same time. The patient's coöperation in making determined and sustained voluntary efforts of flexion and extension is more important than any other measure, and it is in this connection that the special value of a suitable form of occupational therapy, such as net-making or weaving, is desirable.

Finger Traction.— In the more advanced cases, manipulation of the stiffened fingers is always followed by unfortunate results, because of the reaction which follows. Baldwin [11] and Danforth's method of finger extension (Figs. 426-430) in a banjo splint will be found invaluable in such cases. This method aims at taking a direct pull from the ends of the

[11] W.I. Baldwin, *Orth. Surg. of the Hand and Wrist. Orthopedic Surgery of Injuries.* Edited by Sir Robert Jones, Oxford Medical Publications, 1921.

fingers in the line of deformity, so as to produce actual separation of joint surfaces; the adherent and thickened capsule is stretched along with the adhesions in the tendon sheaths. The traction should be continued in the line of deformity until evidence of separation of joint surfaces is seen by depression of the skin over the knuckles and by roentgenograms. The pull should not be greater than four or five ounces. The direction of the line of traction should then be altered, day by day, in the direction of flexion, until, at the end of a week or a month, complete flexion is obtained. The traction is released four or five times a day to permit massage and active motion. The ability to perform actively what has been gained passively is the index to the speed for altering the angle of traction. The interphalangeal joints, although covered by the adhesive strips, share in the traction and increase their range of movement *pari passu* with the metacarpo-phalangeal joints.

CHAPTER X

THE VERTEBRAL COLUMN

ANATOMICAL CONSIDERATIONS

The Spine as a Whole.—The spine is a flexible column, composed of a series of vertebræ and intervertebral discs, held together by strong ligaments, and supported by muscles. It forms the central axis of the skeleton, provides protection for the spinal medulla, and supports the head, trunk and upper extremities. It allows movements of flexion, extension, side-bending, and rotation. While the levels in the column at which certain motions take place and have their greatest range are constant in all spines, it should be recognized that the amount of flexibility varies considerably in different individuals, depending upon whether the patient is of slender, normal, or heavy build. In the case of the slender type of individual with small bones and shallow articular facets, the spine is much more flexible than in the heavy type of anatomical structure with the massive column and deep joints. What is normal for the individual patient must always be considered when examining the movements of the spine.

In early life there are thirty-three vertebræ. The upper twenty-four remain separate throughout life and are termed true, movable, or pre-sacral vertebræ. In the adult, the lower nine are fused to form the bodies of the sacrum and coccyx, and are called false, fixed, or immovable vertebræ. The twenty-four movable vertebræ are divided regionally into seven cervical, twelve dorsal, and five lumbar vertebræ. Numerical variations are found occasionally.

The Individual Vertebræ.—A typical vertebra is composed of a body, a neural arch, and a number of processes. The neural arch is composed of two parts, and consists of two pedicles and two laminæ supporting four articular processes, two transverse processes, and one spinous process. Ossification in a vertebra takes place from three primary centres, one for the body and one for each side of the neural arch with its processes. Five secondary centres appear at about puberty for the tips of the spinous and transverse processes and for the upper and lower margins of the vertebral bodies.

The first and second vertebræ differ fundamentally in structure (Figs. 435, 436). The atlas has no body or spinous process, being formed by two lateral masses and ventral and dorsal arches. The conformation of the occipito-atlantal articulation allows it to subserve the motion of nodding the head in the antero-posterior direction, and there is no spinous process present on the atlas to prevent free extension. The axis has a strong body and its upward prolongation forms the odontoid process, which embryologically is the missing body of the atlas. The atlas and the skull rotate around the odontoid process as on a pivot, held in place by the strong transverse ligament. The axis is remarkable for its large and bifid spinous process which constitutes an important landmark, being the first spinous process to be palpated below the skull in the nuchal furrow.

Articulations.—The vertebral bodies articulate with each other by means of the intervertebral discs, which have resistant semi-fluid centres, but elastic, compressible, peripheral layers, so that rocking motion or rotation in any direction is permitted. The spinal arches are joined by articular processes projecting upward and downward in pairs from each vertebra. The joints thus formed are true articulations, lined with cartilage, and surrounded by a capsule. The shape of these articular processes varies, however, in different segments of the spine, and as their function is to limit the movement of the vertebræ, it will be seen that the type of motion permitted at different levels is directly related to the shape of the process.

Ligaments.—The intervertebral discs are twenty-three in number and vary in height in different parts of the spine. They are high anteriorly in the cervical and lumbar regions and so help in the formation of the normal spinal curves. Weber gives the proportion

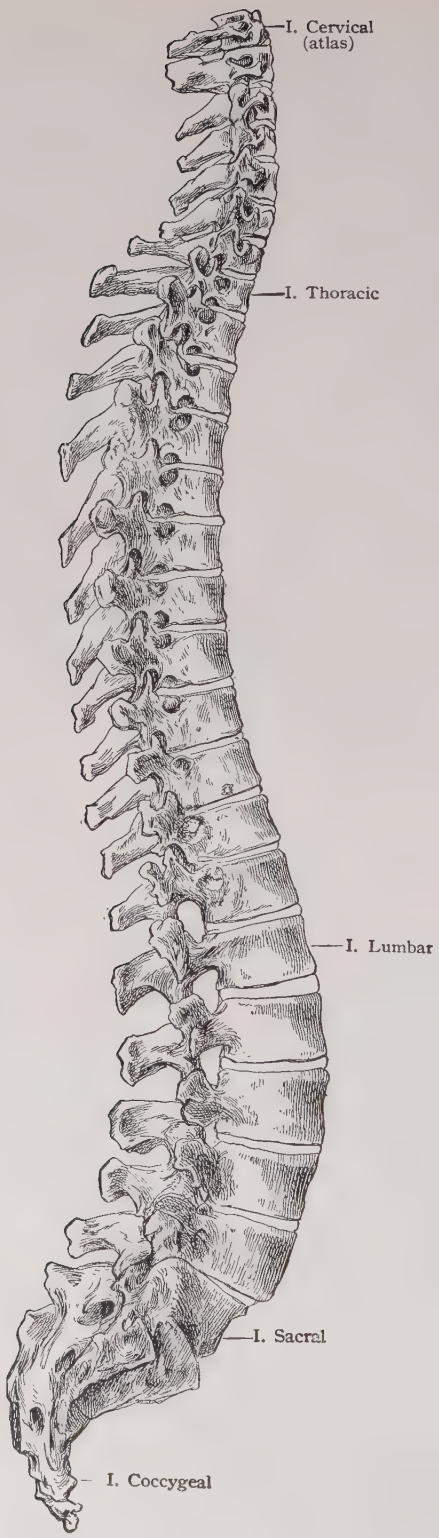


FIG. 431.—Lateral view of normal spine. (Piersol: Human Anatomy.)

of the height of all the discs to the height of all the vertebræ, excluding the sacrum, as 1 : 5. They form strong, elastic connecting links between the bodies and are firmly attached to their borders and to the anterior and posterior common ligaments.

The vertebræ are bound together by strong anterior and posterior common ligaments, extending from the sacrum to the occiput, and covering the bodies and the discs. The posterior longitudinal ligament begins at the second cervical vertebra and is attached to

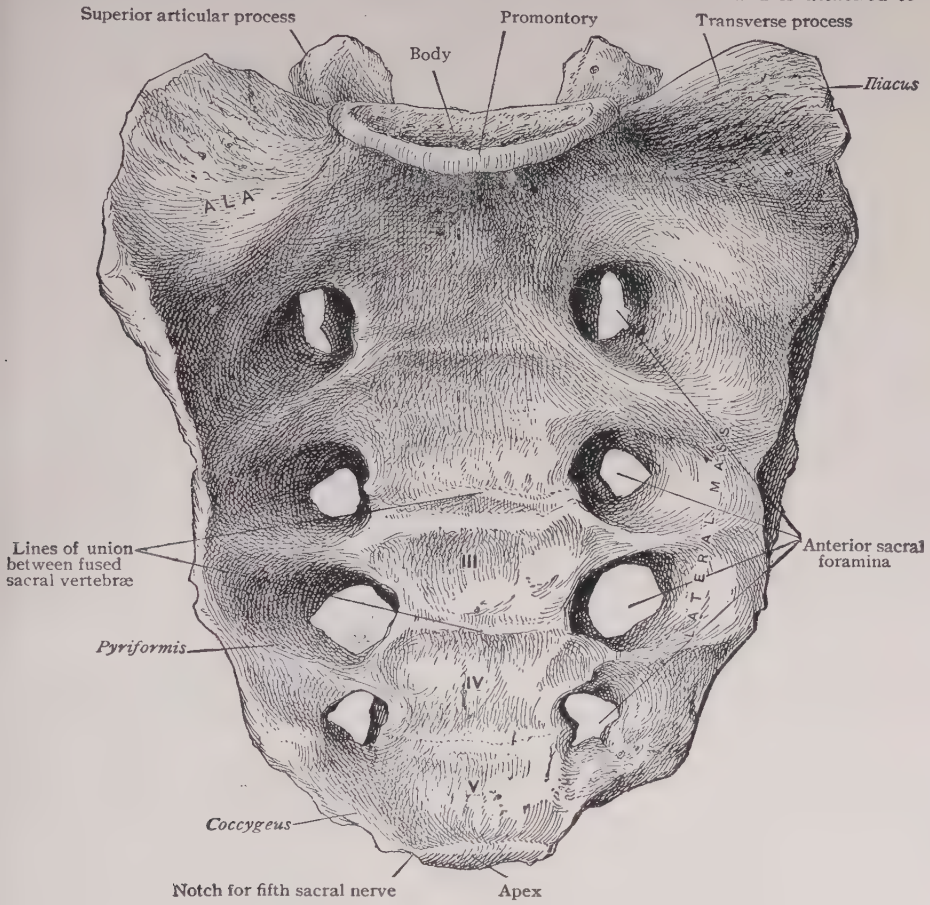
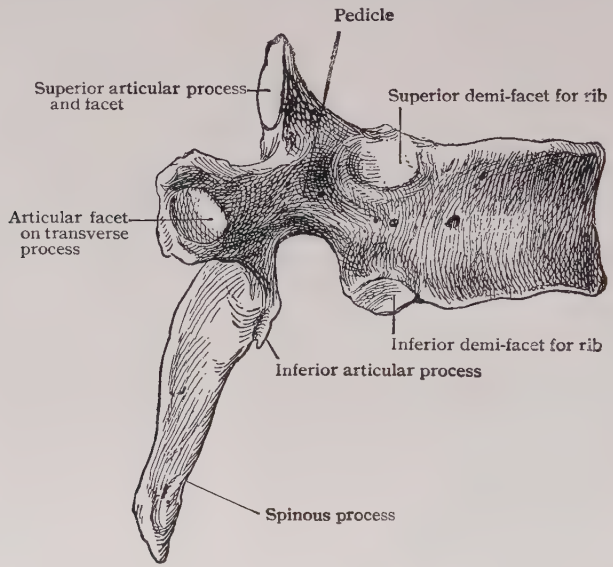


FIG. 432.—Anterior view of the sacrum. (Piersol: Human Anatomy.)

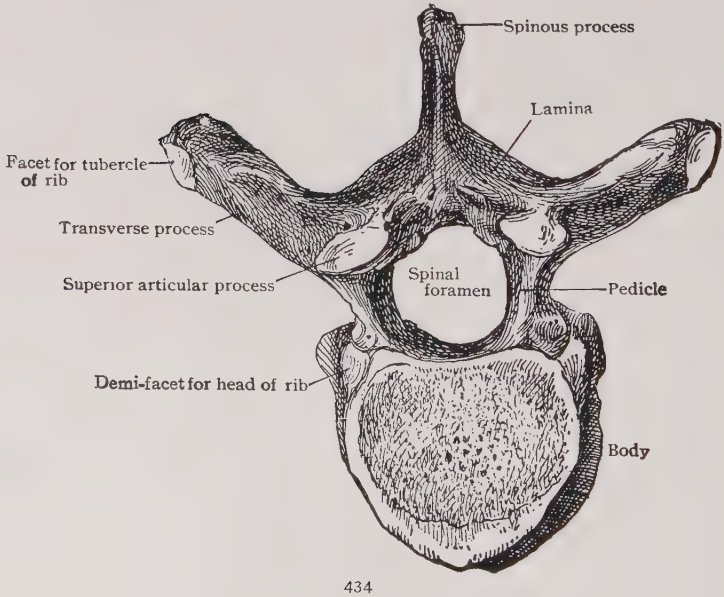
the posterior surfaces of the bodies. The ligamenta flava connect the vertebral arches, while the intertransverse, interspinous, and supraspinous ligaments connect the transverse and spinous processes respectively.

Physiological Curves.—The spine normally presents four curves in the upright position, which, in relation to the dorsal surface, consist of a cervical concavity, a dorsal convexity, a lumbar concavity, and a sacro-coccygeal convexity (Fig. 431). The dorsal and pelvic curves may be considered as primary curves, as these segments form parts of the pelvis and thorax, and are comparatively rigid portions. The lumbar and cervical regions are the flexible connecting links and the chief balancing agents because they possess the greatest degree of movement. The cervical curve appears when the child begins to hold the head erect; the lumbar curve develops only when the vertical position

is first assumed. They are, therefore, secondary curves, intended to compensate for the normal inclination of the pelvis and the posterior convexity of the dorsal region.



433



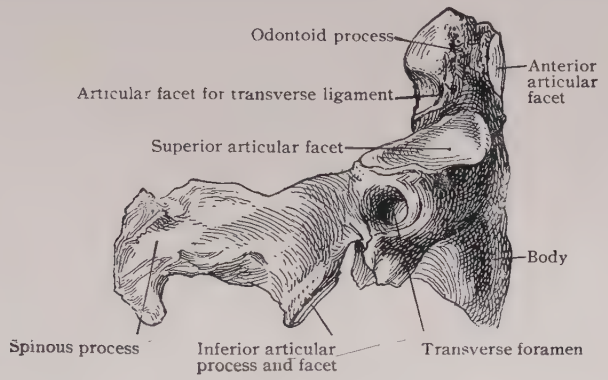
434

FIGS. 433 and 434.—(433) Sixth thoracic vertebra from the side. (434) Same from above.

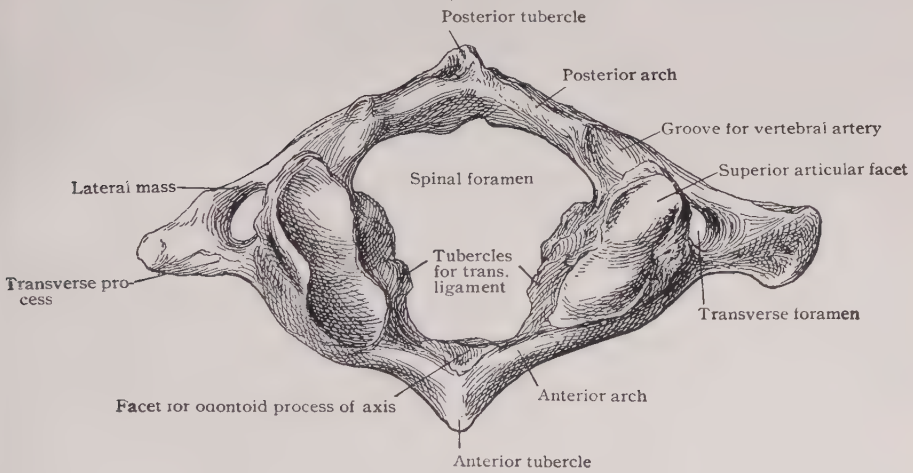
The Spinal Medulla.—The vertebral canal contains the spinal medulla and its three covering membranes. The dura is applied to the bony walls of the canal, but is separated from them by a relatively thick layer of loose, fatty tissue with a rich vascular supply and extensive venous plexuses. It sends fibrous prolongations to invest

the spinal roots as they emerge. The arachnoid is a delicate membrane which lies just beneath and in close relation to the dura. The pia is a thin membrane which intimately invests the spinal cord. The arachnoid is joined to the pia by fine strands of tissue, but is separated from it by the spinal fluid, which fills the subarachnoid space and extends downward as far as the upper segment of the sacrum.

In the adult the spinal medulla ends at the level of the disc between the first and second lumbar vertebræ. The cervical enlargement, comprising the lower four cervical



435



436

FIGS. 435 and 436.—(435) Lateral view of the axis. (436) The atlas from above. (Piersol: Human Anatomy.)

and upper two thoracic segments, ends opposite the seventh cervical spine. The lumbar enlargement lies opposite the lower three dorsal spines. One pair of spinal nerves leaves each segment, inclining downward and outward to their exits from the canal, until in the lumbar region they run downward, parallel with the filum terminale, and form the cauda equina. The manner in which the spinal nerves emerge from the spinal canal, passing through the intervertebral foramina in close relation to the articular processes, exposes them to injury in compression fractures and dislocations. The cord being much shorter in the adult than the spinal column, it follows that the tips of the spinous processes lie at a considerably lower level than the corresponding segment of the cord; one below in the cervical region, two below in the upper dorsal region, and three below in the lower dorsal region.

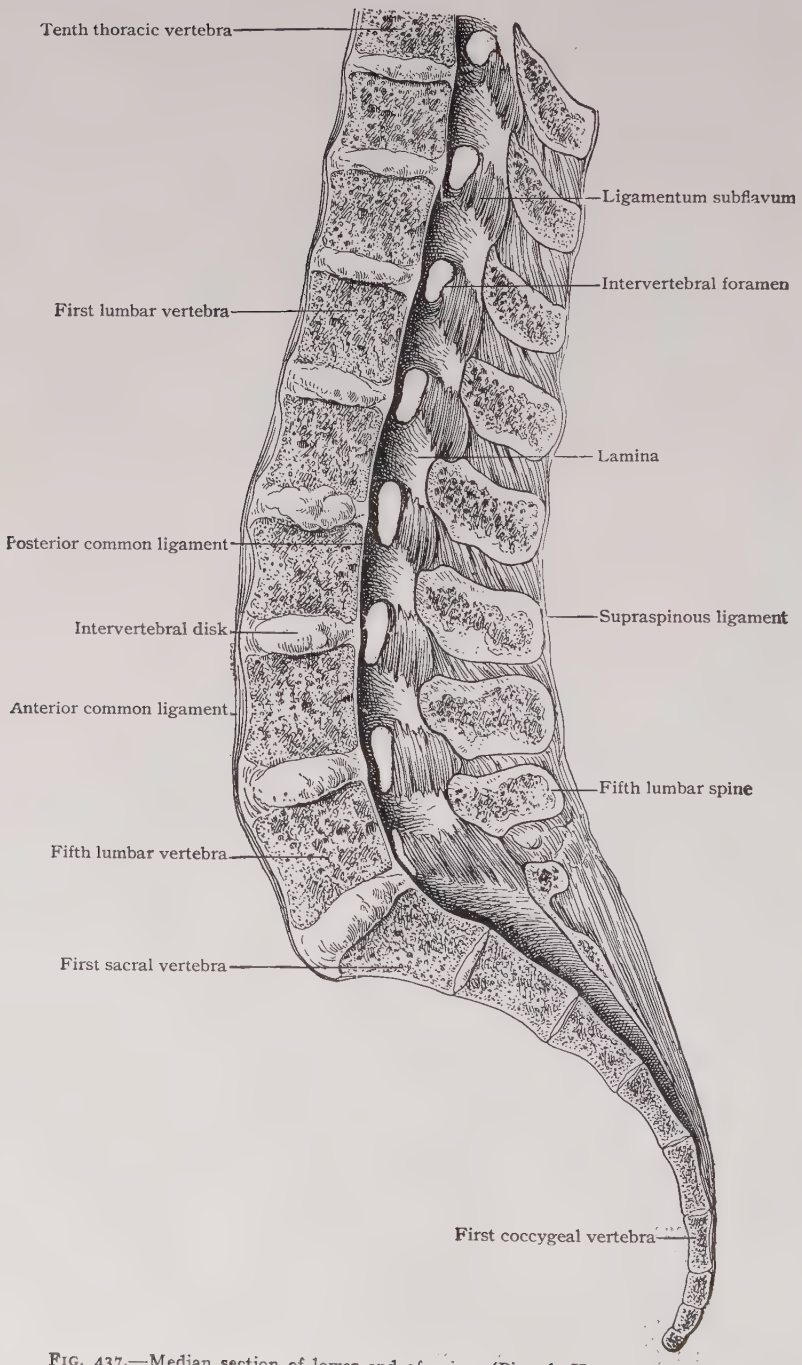


FIG. 437.—Median section of lower end of spine. (Piersol: Human Anatomy.)

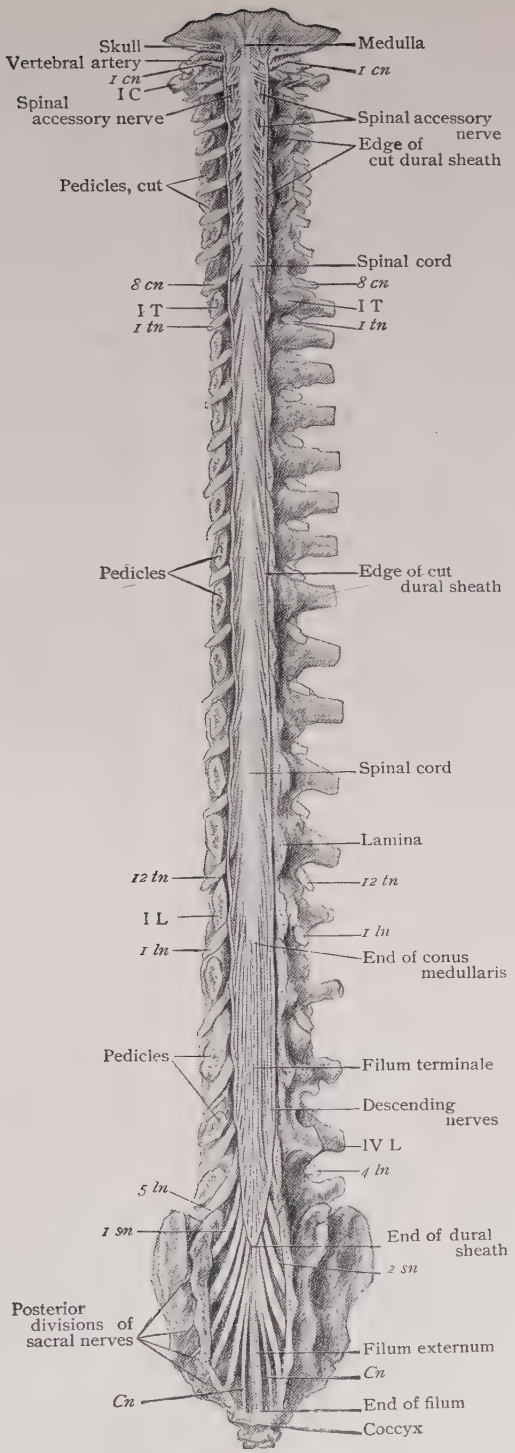


FIG. 438.—View of spinal cord with membranes. The posterior wall of the vertebral canal has been removed and the dural sheath opened. (Piersol: Human Anatomy.)

Movements of the Spine.—The cervical spine possesses the greatest range of movement and is consequently very frequently the site of twists, strains, and dislocations. The occipito-atlantal joints permit only of movements in the antero-posterior plane, such as those represented by nodding the head forward and backward. Rotation of the head on the spine, as in looking from side to side, is accomplished at the atlanto-axoid articulations. The midportion of the cervical spine is relatively less movable than the portions above and below it, and lateral bending, as in approximating the ear to the shoulder, is the predominant motion. In the lower cervical region the movements of flexion and extension are chiefly in evidence.

The dorsal region, on account of its relations to the ribs, is a relatively fixed portion of the spine in comparison with the cervical and lumbar segments. Nevertheless, the

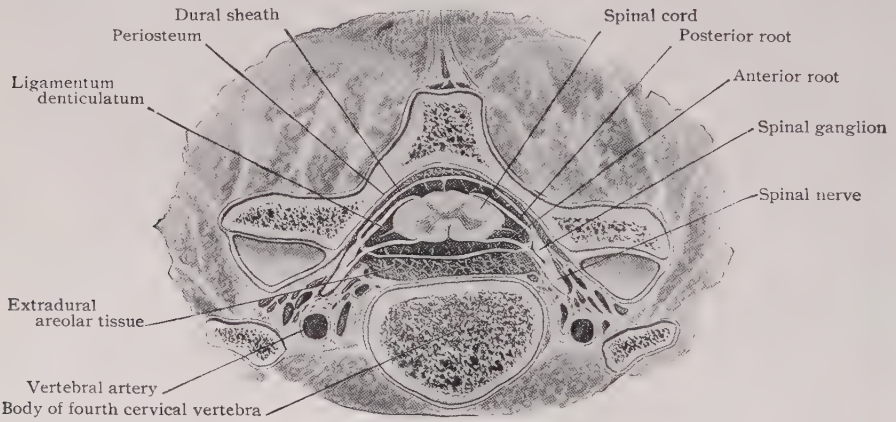


FIG. 439.—Transverse section of vertebral canal at the level of the fourth cervical vertebra. Relations of the spinal cord in the canal are shown. (Piersol: Human Anatomy.)

articulations permit movements of rotation, flexion, and extension, and to a slight degree, lateral bending. The motion between the individual vertebræ is slight, but the total result is considerable.

The lumbar region permits very marked movement in the antero-posterior and lateral planes, but, owing to the crescentic shape of the articular facets, movements of rotation are scarcely at all possible. Motion is most marked at the joints representing the junction of the fixed and movable portions of the spine; namely, the dorso-lumbar and lumbo-sacral articulations.

Movements in the antero-posterior and lateral planes are checked by the tension of the ligaments on the sides of the bodies opposite to the direction of the movement and by the resistance to compression of that edge of the intervertebral disc toward which the motion occurs. Extension of the spine is limited by the contact of the spinous processes and the locking home of the articular facets.

Surface Anatomy.—The finger applied to the midline in the nuchal and spinal furrows palpates the tips of the spinous processes, those in the dorsal and lumbar regions being made more evident by flexing the spine. The second sacral spine is placed at the level of the posterior superior iliac spine, and a line joining the summits of the iliac crests crosses the spine of the fourth lumbar vertebra. The tips of the spinous processes in the lumbar region occupy the same horizontal level as their respective bodies, in the middle and lower dorsal region they lie opposite the body of the vertebra below, while in the cervical and upper dorsal regions, they lie opposite the lower border of their respective vertebræ. The anterior surfaces of the bodies of the two upper cervical vertebræ may be palpated by the insertion of a finger within the posterior pharynx.

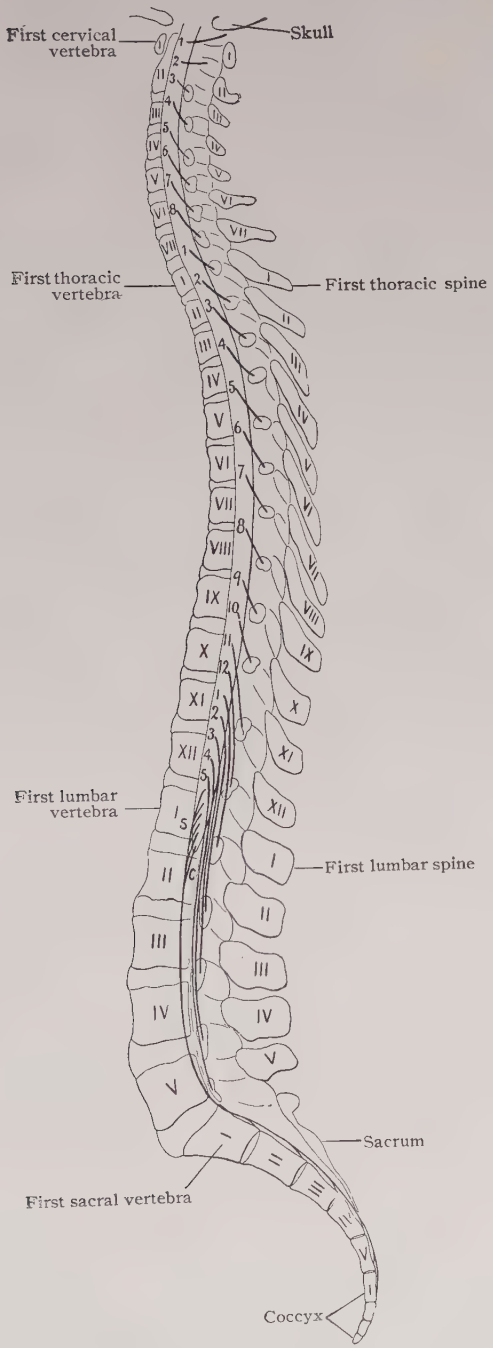


FIG. 440—Diagram based on frozen section showing the relations of the bodies and spinous processes of vertebræ to the various levels at which the spinal nerves emerge from the canal. (Piersol: Human Anatomy.)

ROENTGENOLOGICAL EXAMINATION

It is very difficult in many cases to obtain roentgenograms of the spine which show all of its structures in clear detail. This is because the rays must pass through the body in its thickest portion and also on account of the irregular contour of the vertebræ and the overlapping shadows. Although the introduction of the Bucky diaphragm has marked a great step forward, the spine still remains a region where the skill of the roentgenologist is most severely tested. By the same token, the surgeon who is

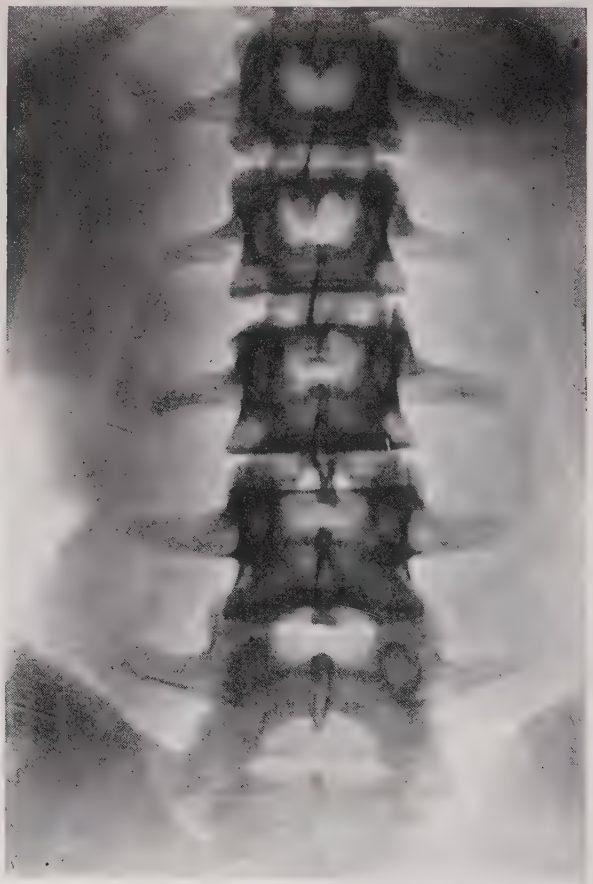


FIG. 441.—Lumbar spine. Slender type. The bodies of the vertebræ are square, the sacrum extends well upward and the transverse processes of the fifth lumbar are well removed from the ilium.

called to treat injuries of the spine must be sufficiently familiar with the normal roentgenological appearance of the region to himself recognize the presence of any pathological abnormality. The roentgenologist labors under the handicap of not knowing the patient's symptoms, and in the case of doubtful pathological findings it is the clinician who is best able to correlate all the evidence and reach the final verdict.

In traumatic conditions the lateral view is particularly important, as it may reveal definite wedge-shaped deformity of a vertebra in spite of normal appearance in the antero-posterior view. Stereoscopic plates are of great value in localizing minute lesions and in revealing the exact nature of the deformity in gross lesions. Chief difficulty in interpreting the findings is encountered in the cervical and dorsal regions. Care should

be exercised to examine the spine over a sufficiently wide area, as failure to centre the tube properly, combined with inaccurate localization of the level of the lesion, may result in completely missing the point of injury.

Anatomical Variations.—Variations from the normal or text-book anatomy are very common in the spine, and familiarity with the appearance of these anomalies is necessary in order to avoid error. The variation may be one of number, shape, or

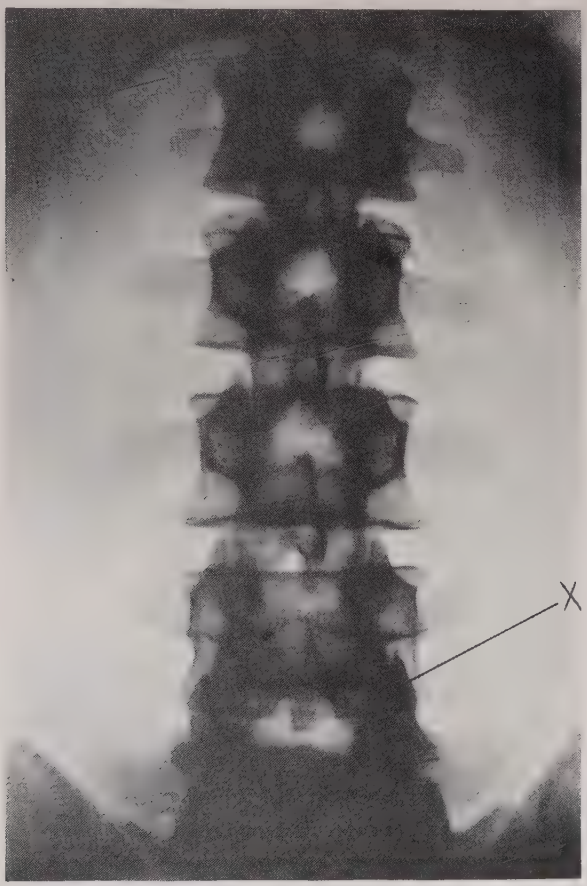


FIG. 442.—Lumbar spine. Heavy type. The width of the bodies is greater than their height and the transverse processes, particularly those of the fifth lumbar, are broad, but not in contact with the ilium. The crescentic shape of the articular processes is well shown at X.

development. Numerical variation, such as the presence of an extra vertebra, is frequently found in the lumbar region; less commonly the normal number of vertebræ is reduced instead of increased. Variation in shape is of frequent occurrence at the points of junction of the cervical and dorsal, dorsal and lumbar, and lumbar and sacral portions of the spine. In the cervico-dorsal region, it commonly takes the form of extra ribs, usually rudimentary in type. In the dorso-lumbar region it has to do with the overdevelopment or failure of development of the ribs or transverse processes. In the lumbo-sacral region the variation chiefly affects the shape of the transverse processes and is in the nature of an incomplete sacralization of the fifth lumbar vertebra. Such variations are frequently asymmetrical (Fig. 443). Other variations may be due to

developmental defects. These include incomplete closure of the spinal arches or spina bifida occulta, usually involving the last lumbar and upper sacral vertebræ (Fig. 445), failure of union of the epiphyses of a transverse process, congenital wedge-shaped vertebræ, usually in the dorsal spine and often associated with a reduction in the number of ribs on one side. Lateral deviation of the spinous processes from excessive crowding together during the formative period of life is a common finding.

FIG. 443.—Lumbar spine. The transverse process on the right side forms a true articulation with the sacrum and ilium. The opposite side is not equally well supported and has tilted downward with the production of scoliosis.

OPTIMUM POSITION FOR FIXATION OF THE SPINE

In considering injuries of the extremities and particularly those in the neighborhood of the articulations, it has been pointed out that in the case of every joint there are good and bad positions for fixation, and that when prolonged immobilization is required, the earliest restoration of function may be expected if the optimum position is employed, and that when ankylosis is likely to be the result, the part should be fixed in the position which assures the maximum usefulness of the part. The same considerations hold in the treatment of injuries of the vertebral column, only the more so because the results of faulty spinal attitudes are not limited to the purely static effects from alteration of

the mechanics of weight bearing, but may be productive of disturbances which affect the general body health.

Bad Posture and Back Strain.—Chronic back strain is commonly the result of habitual use of the spine in a position of bad posture, that is, with the body sagged and the physiological curves of the spine exaggerated. In such position the spinal joints are held at their limits of motion and the ligaments which resist these movements are

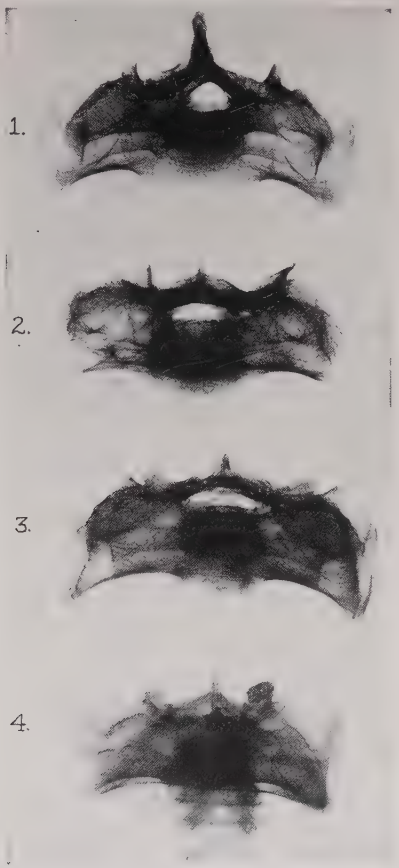


FIG. 444.—Variation in shape of articular processes of sacrum. Roentgenograms of specimens. 1.—Normal processes, both crescentic. 2.—Asymmetrical variation, left process crescentic, right flat. 3.—Symmetrical variation. Both processes flat. 4.—Asymmetrical variation. Both processes small but one on right particularly undeveloped.

constantly under tension or strain. In cases of spinal fracture, after union has been obtained, it is a common experience to find pain and disability persisting longer than would be reasonably expected from the lesion itself, and it is probable that chronic back strain is an important factor in causing this prolongation of symptoms. The best prophylaxis of such a condition is early fixation of the spine in the position of optimum function.

Faulty Posture and Impaired Health.—But the effects of habitually bad posture are not limited alone to the production of back strain. All parts of the body are related and no part can be used wrongly without secondary effect on other structures. When the spine sags, and its curves become exaggerated, the angle of the ribs is depressed, the chest flattens, and the diaphragm descends. With a position of marked lumbar

lordosis, the abdominal muscles are no longer necessary for the maintenance of the erect posture, and they become atonic and the abdominal wall is relaxed. The abdominal viscera, being on the one hand deprived of their normal ventral support, and on the other pushed downward by the decreased capacity of the upper abdomen, come to lie in

FIG. 445.—Congenital defect. Spina bifida occulta. Imperfect closure of spinal arch of first sacral segment.

an abnormally low position. These conditions alter the physiology of the thoracic and abdominal organs and may lead to considerable impairment of health.

Correct Position.—In spinal fractures prolonged fixation is necessary, and great care should be taken to see that fixation is accomplished in a position without deformity and with the spine in a position which assures strong painless use and the maximum function of the related body structures. Such a position is one in which the normal curves of the spine are slight, the lumbar curve in particular being flattened, the abdomen

retracted, and the costal margin well elevated. This position is not only the best from the standpoint of function, but also to the greatest degree promotes the comfort of the patient. Undue pressure on the upper abdomen is avoided and the placing of so-called dinner pads to permit distention of the stomach is unnecessary. If a plaster jacket is used, it is necessary to carry the lower anterior border well down to the pubis in order to support the abdomen from below; otherwise, a space is opened up when the patient is erect through which a relaxed abdomen may escape and fixation of the lumbar spine in the correct position is lost.

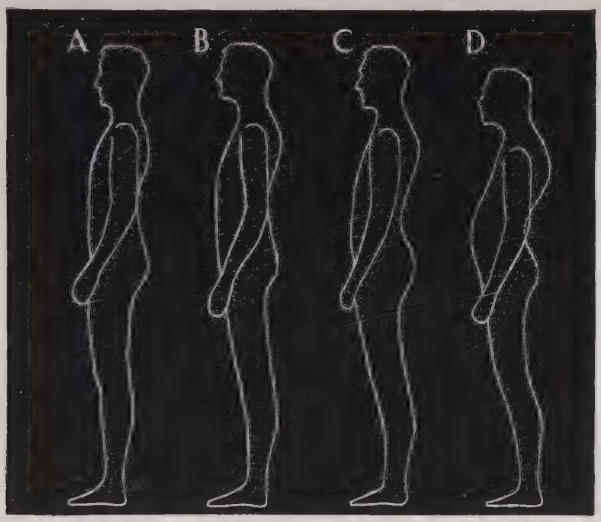


FIG. 446.—Figures illustrating good and bad bodily mechanics, based on an examination of 700 Harvard freshmen.

Group A. 7.5%	Group B. 12.5%	Group C. 55%	Group D. 25%
Good mechanical use of the human body.	Fairly good mechanical use of the human body. Note changes from Group A.	Bad mechanical use of the body. Note changes from Group A.	Very bad mechanical use of the body. Note changes from Group A.
1. Head straight above chest, hips and feet.	1. Head too far forward.	1. Head forward of chest.	1. Head still farther forward.
2. Chest up and forward.	2. Chest not so well up or forward.	2. Chest flat.	2. Chest still flatter and farther back.
3. Abdomen in or flat.	3. Abdomen, very little change,	3. Abdomen relaxed and forward.	3. Abdomen completely relaxed, "slouchy."
4. Back, usual curves not exaggerated.	4. Back, very little change.	4. Back, curves are exaggerated.	4. Back, all curves exaggerated to the extreme.

INJURIES OF THE VERTEBRAL COLUMN

GENERAL CONSIDERATIONS

Causation.—Fractures and dislocations of the spine are encountered most frequently in men whose occupations expose them to the possibility of severe injury, and in active boys, as the result of participation in strenuous forms of athletics. The causative violence may be direct or indirect in its action, more commonly the latter. Indirect violence produces its effect by causing hyperflexion or hyperextension of the spine or a shortening in the longitudinal axis beyond the limits of its elasticity. Hyperflexion, as from a heavy fall of rock or coal upon the bent shoulders

when the individual is in the stooping posture, is the most common mechanism and the spine gives way not at the point struck, but at the angle of greatest flexion, that is, at the point of junction of the fixed and movable portions of the column, usually the dorso-lumbar junction.

"Compression fractures" or "crush fractures" are most common in the dorso-lumbar region, where flexion is much restricted; on the other hand, twists and dislocations occur most frequently in the cervical region, the most flexible portion of the spine. Direct violence from a blow or a bullet or stab wound may be responsible for isolated fractures of the vertebral arches or of the spinous and transverse processes. More rarely violence resulting from muscular action alone may tear off a spinous or transverse process.

Association of Cord and Vertebral Lesions.—Spinal injuries are practically never dangerous from the nature of the bony lesion alone, although, because they frequently result from the action of severe violence, they are not infrequently complicated by the presence of other serious injuries of the visceral or skeletal systems. It is from the intimate relationship of the spinal medulla to the vertebral column and the frequent association of such injuries with lesions of the cord that they derive their great importance. In the event of such an accident, the resulting symptoms are of two orders, the first due to the bony injury and related to the function of the spine as a part of the body skeleton, and the second due to nerve disturbance from injury to the cord or spinal nerves.

Any of the various injuries of the spine may inflict damage upon the spinal medulla and nerve roots. While in such accidents the extent or severity of the two lesions is not necessarily proportionate, a severe injury of the spine being accompanied by little damage to the cord or *vice versa,* it is more commonly the case that total lesions of the spine, such as complete dislocation or fracture dislocation, are associated with severe and irreparable crushing injuries of the cord. In the partial or incomplete bony injuries, such as are represented by isolated dislocations of an articular process, fracture of the spinal arches, or of the spinous or transverse processes, and finally by compression-fracture of the bodies of the vertebræ, the cord is not usually damaged.

A. and J. Boeckel [1] have collected ninety-five cases of fracture of the spine without injury to the cord, and in Wallace's [2] series of seventy-eight cases of "crush fracture," paralysis was absent in fifty-five cases or seventy per cent. Indeed with improved roentgenologic methods, it has been shown that certain fractures and dislocations of the spine may result from comparatively insignificant trauma, and that they commonly escape diagno-

[1] A. and J. Boeckel, *Rev. de Chirurgie*, Vol. 43, p. 649; Vol. 44, pp. 48 and 285.
[2] J. O. Wallace, *Jour. Bone and Joint Surg.*, Jan., 1923, p. 28.

sis because of the erroneous impressions that spinal fractures result only from severe violence and are practically always associated with paralysis of greater or less degree.

The following injuries will be considered:

I. ISOLATED DISLOCATION OF AN ARTICULAR PROCESS
II. TRAUMATIC LESIONS OF THE ATLAS AND AXIS
III. TRAUMATIC SPONDYLOLISTHESIS
IV. ISOLATED FRACTURE OF THE SPINOUS PROCESSES OR LAMINÆ
V. ISOLATED FRACTURE OF THE TRANSVERSE PROCESSES
VI. COMPRESSION FRACTURE OF THE VERTEBRAL BODIES
VII. TOTAL DISLOCATION AND FRACTURE DISLOCATION OF THE SPINE
VIII. INJURIES OF THE SPINAL CORD ASSOCIATED WITH FRACTURES AND DISLOCATIONS OF THE VERTEBRAL COLUMN

I. ISOLATED DISLOCATION OF AN ARTICULAR PROCESS

Occurrence.— Dislocation of an articular process occurs most commonly in the cervical region and is usually unilateral. In the dorsal and lumbar regions, the articular processes are nearly vertical in shape, and dislocation without fracture can only occur with great difficulty. In the cervical region, on the other hand, the articular processes are more nearly horizontal, and because there is normally but little movement of rotation possible, it is easy by a sudden twist to rotate one articular process forward over the one below, so that it either remains incompletely dislocated on the crest of the inferior process or slips forward to fall into the intervertebral notch (Fig. 447). Occasionally, both articular processes may be displaced forward by strong flexion of the neck, though bilateral luxation without fracture is rare.

Cervical Dislocation.— The vertebræ most commonly affected in unilateral luxation are the fourth, fifth and sixth cervical. The cord is rarely involved in such injuries, nor would this be expected, since the bodies of the vertebræ are not displaced. There may, however, be pressure upon the related nerve root with symptoms of pain and neuralgia in its area of distribution. The lesion is commonly produced by an unexpected twist which forcibly flexes and rotates the neck, although certain of the cases have been produced by muscular action in combination with certain movements of the body such as happened in the case reported by Walton, where there was a sudden turn of the head while running around a corner.

Diagnosis.— The patient complains of pain and stiffness in the neck, and the head is fixed in a characteristic attitude of deformity, the position of which may be inferred from an analysis of the displacement. In unilateral luxation, the head is rotated toward the opposite or unaffected side, and, if the dislocation is complete, the neck is at the same time inclined

toward the side of the lesion. In the event of the articular process being caught on the crest of the articular process below and an incomplete luxation, then the head is both rotated and inclined away from the side of the lesion. The muscles are usually in spasm, and both sterno-mastoid muscles are affected instead of one alone, as in simple torticollis. So long as motion is not attempted, there is no pain, but gentle attempts to straighten

FIG. 447.—Isolated dislocation of the third cervical vertebra. (Beesley and Johnston: Manual of Surgical Anatomy.)

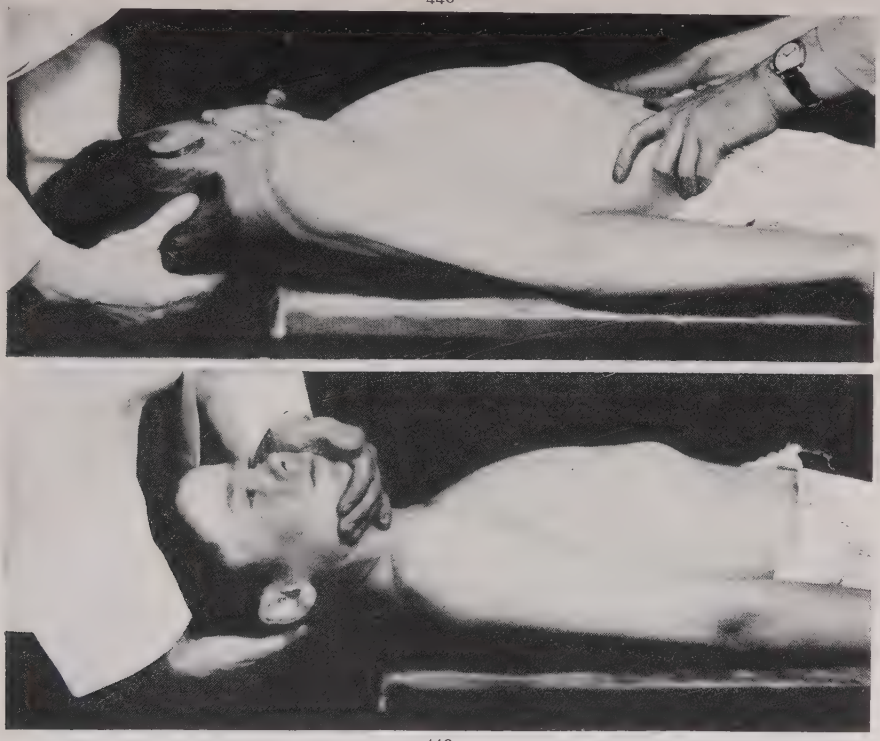
the head are painful and unsuccessful. The transverse process of the affected vertebra is displaced forward in the neck on the side of the lesion, where its presence may be recognized by palpation. Deviation of the spinous process and pain on pressure are demonstrable in the nuchal furrow. In bilateral dislocation the head is carried forward and tilted directly backward. The lesion may be demonstrated by roentgenological examination.

Treatment.—Immediate reduction by manipulation should be attempted under ether anæsthesia after the method advised by Walton.[3] The aim of manipulation is to unlock the displaced articular process by dorsolateral flexion, that is, by bending the head obliquely backward on the side toward which the face is turned by the dislocation, at the same time slightly increasing the rotation of the head in the direction of the original

[3] G. L. Walton, *Annals of Surg.*, XL, 654, 1904. *International Clinics*, Vol. I, Eighteenth Series, 1908.

displacement. After the articular process has been freed, the head is rotated in the opposite direction, and the test of reduction is the ability to perform this movement freely. Only a very slight amount of force is required, and Walton particularly advises against traction being used at all. It is interesting to note that a certain number of cases of unilateral

448



449

FIGS. 448 and 449.—Cervical dislocation. Method of reduction. (448) The head is first rotated in a direction to increase the deformity and then flexed to the opposite side in the dorso-lateral direction. (449) This frees the articular processes and replacement is accomplished by rotating the head back to the median line.

dislocation of the cervical vertebræ have been reduced spontaneously during sleep and under ether. After reduction, the patient should be kept in bed with light extension applied to the head (Fig. 450) for ten to fourteen days, when he may be allowed up in a Thomas collar, which is worn for three to four weeks (Fig. 451).

Treatment in Late Cases.—When reduction is unsuccessful or, in late cases, where its attempt is inadvisable (after six weeks), head traction should be applied immediately and maintained in the recumbent position for six weeks, followed by the use of a leather collar (see Fig. 451) for four to six weeks. A compensatory rotation of the spine takes place at

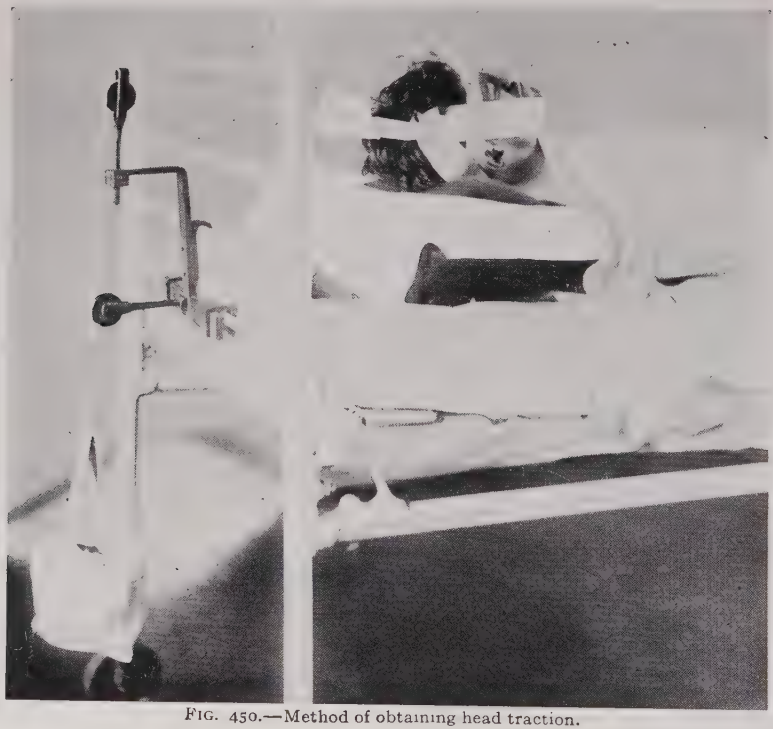


FIG. 450.—Method of obtaining head traction.

FIG. 451.—Reinforced leather collar used in certain cases of injury of the cervical spine. (Fracture Service, M. G. H.)

a lower level and eventually leads to practically complete disappearance of the deformity and fair function.

In bilateral dislocations an attempt at manipulative reduction should be made, employing the same principles as in unilateral cases. The neck is flexed and traction applied to the head in an upward and backward direction.

Dislocations of the Dorsal and Lumbar Spine.—Very few cases are reported, and nearly all are complicated by a fracture of the articular process or of the body. Charles Bell [4] in 1824 reported an uncomplicated case of dislocation in the dorsal region, in a young girl who was run over by

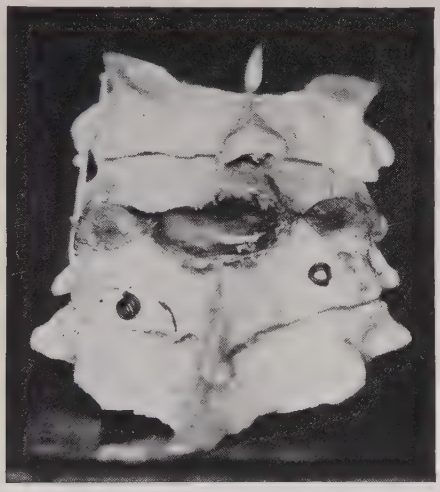


FIG. 452.—Bilateral dislocation of the second cervical vertebra. (Specimen from Warren Anatomical Museum.)

a stage-coach. She survived the accident and died a year later of croup. At the postmortem, the last dorsal vertebra was found completely displaced to the left side of the first lumbar vertebra. J. N. J. Hartley [5] reports an uncomplicated and incomplete dislocation laterally between the first and second lumbar vertebræ which was reduced operatively by Sir Harold Stiles. He explains the rarity as being due to the fact that in forced flexion and rotation of the spine, the cancellous bone of the bodies of the vertebræ yields more readily than the strong ligaments which bind together the spinous processes and the neural arches. He also points out that the complete form laterally could hardly occur without a fracture of the articular processes.

II. TRAUMATIC LESIONS OF THE ATLAS AND AXIS

Occurrence.— Until the last ten to fifteen years it was commonly believed that traumatic lesions of the atlas and axis, such as fractures or dislocations, were inevitably and almost instantaneously fatal from severance or com-

[4] Bell, *Injury of the Spine and Thigh Bone*, 1824.
[5] Hartley, *Edin. Medical Journal*, Vol. XXIX, No. 1, p. 37.

pression of the cord. Since then there have appeared a succession of articles dealing with this subject, each reporting groups of cases representing all types of lesions in which the patients not only survived the accident, but exhibited on the whole surprisingly little inconvenience from it. It thus appears that these injuries are much more common than was formerly supposed and also that the previously accepted views as to their high mortality are wrong. As in the case of so many other bony injuries, we owe this increase in knowledge to the more frequent use of the roentgen ray in supposedly minor injuries and to the improvement in roentgenologic technic.

The different injuries which have been described correspond more or less closely in type and may be grouped under the following headings:

1. SIMPLE ROTARY DISLOCATION OF THE ATLAS
2. DISLOCATION OF THE ATLAS WITH FRACTURE OF THE AXIS
3. FRACTURE OF THE ATLAS

Production.— Most of the lesions are produced by severe violence acting on the vertex and transmitted downward to the vertebral column, such as represented by a fall down-stairs or striking bottom with the head when diving. On the other hand, not a few cases are on record in which injury resulted from surprisingly little trauma, such as a sudden twist of the head or a jerk of the neck. It is possible that pre-existing disease of the spine may have facilitated the injury in such cases.

Rotary Dislocation of the Atlas.—Rotary dislocation of the atlas is the most common injury of this region. The lesion is essentially the same as that described in the previous section under the heading of isolated dislocation of the articular processes. The displacement is of a rotary character and almost always unilateral, one articular process of the atlas slipping forward and either catching on the anterior edge of the corresponding facet of the axis or falling forward into the intervertebral notch. Corner [6] points out the fact that little support is derived from the ligaments except at the extremes of motion, this arrangement being necessary in order to permit free movement of the head. The load is, therefore, borne by the muscles, which are powerful and well able to give protection from injury except in the case of violence acting from above downward, or in sudden movements, at a moment when the muscles are off guard. In uncomplicated dislocation, cord injury is of rare occurrence because of the large size of the neural arch and the limited displacement.

Dislocation of the Atlas with Fracture of the Axis.—Dislocation of the atlas may be complicated by a fracture of the odontoid process of the axis. The presence of this associated lesion is difficult to recognize because

[6] Edred M. Corner, *Annals of Surg.*, Jan., 1907, p. 9.

displacement of the process is almost necessarily fatal, and it is, therefore, only in the cases with little or no displacement that one is called upon to make a diagnosis. Yet the importance of recognizing it is shown by the fact that the odontoid was fractured in six of the eight fatal cases of Corner,[7] while in the ten cases which survived, it was broken only once. It is also

FIG. 453.—Forward bilateral dislocation of the atlas on the axis.

of interest to note that in only two of his eight fatal cases did death or even paralytic symptoms appear soon after the injury. In the other cases there were intervals varying from twenty-three days to several years, and death resulted either from injudicious movements on the part of the patient or his physician, or from myelitis caused by irritation or callus formation.

Fracture of the Atlas.— Fracture of the atlas with or without accompanying dislocation also apparently occurs with considerable frequency. Jefferson,[8] in analyzing the mechanism of this injury, points out that it consists of a tension fracture of the atlas with spreading of the ring

[7] Edred M. Corner, *Annals of Surg.*, Jan., 1907, p. 9.
[8] Jefferson, *Brit. Jour. of Surg.*, Jan., 1920.

due to divergence of the lines of force as they are transmitted downward to the lateral masses from the condyles of the occiput. The posterior arch being weaker than the anterior, gives way more frequently. Jefferson reports that recovery occurred in forty-five per cent. of uncomplicated fractures, and the frequently non-fatal character of the injury is explained by the tendency to centrifugal displacement of the fragments. When complicated by an injury to another vertebra, it is usually a fracture of the odontoid, or a rotary dislocation of the atlas that occurs.

Diagnosis.— The diagnosis is made from the history of the injury, the rigidity of the neck muscles, and the asymmetrical position of the head. The median line of the face lies to one or the other side of the median line of the body with the chin pointing away from the side of the lesion, and, in case of a complete dislocation, with the head inclined toward the side of the luxation. Severe occipital neuralgia from irritation of the greater occipital nerve is of considerable importance in localizing the level of the injury. By palpation, it is possible occasionally to demonstrate an abnormal prominence of the spinous process of the axis which, according to Mixter and Osgood,[9] signifies a fracture of the odontoid. In case of dislocation, it is possible by palpation through the mouth to demonstrate two abnormal prominences, one due to the forward displacement of one side of the atlas, and the other, lying a little lower and on the opposite side, to the exposure of a portion of the axis by the slipping backward of that side of the atlas.

Roentgenologic Examination.—The clinical evidence of injury in all cases requires confirmation by roentgenologic examination. The lateral view reveals forward displacement of the atlas or fracture of the arch, while the antero-posterior view shows lateral asymmetry of the articulation, stereoscopic roentgenograms being particularly valuable for this purpose. The antero-posterior skiagram is only of value in revealing injury of the atlas or axis when it is made through the wide open mouth. In this way a clear view of the odontoid, lateral masses, and the articulations is obtainable.

Treatment.— In case of uncomplicated rotary dislocation of the atlas, reduction by manipulative means according to the method of Walton (see p. 344) should be attempted. Before proceeding, however, with this phase of the treatment, the surgeon should employ every available means to convince himself that the luxation is not complicated by fracture. Many successful reductions by the manipulative method have been reported, but sudden death or paralysis has also resulted from the attempt. There is evidence to show that this has been caused by the displacement of a bony fragment in an injury where the fracture part of the lesion had

[9] S. J. Mixter and R. B. Osgood, *Amer. Journ. Orth. Surg.*, Feb., 1910, p. 348.

not been recognized. In cases of fracture or fracture-dislocation, or in others of doubtful diagnosis, we advise conservative treatment with prolonged immobilization, at first in the Minerva type of plaster jacket (Fig. 454), which supports and fixes the head, later replaced by the leather Thomas collar (Fig. 451), made from a plaster mould of the head, shoulders, and neck. It is probable that fixation is necessary for a period of years in severe fractures, particularly when the odontoid is involved. Weak fibrous union of the fragments is a late pathological finding, and under such conditions slight trauma may result in death. Mixter and Osgood [10] doubt if fractures of the odontoid ever unite, and advise operative fixation. They devised the plan of passing a heavy silk ligature under and over the arch of the atlas and then tying it firmly to the spine of the axis, which is ideally situated for this procedure. A fascial ligament might be used for the same purpose.

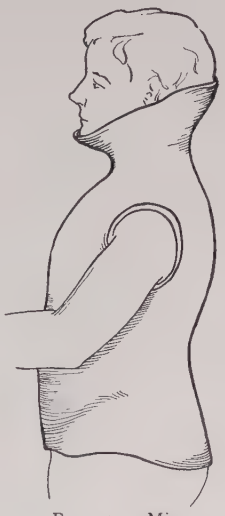


FIG. 454.—Minerva type of plaster jacket required in the convalescent period of treatment of fractures of the upper dorsal spine.

III. TRAUMATIC SPONDYLOLISTHESIS

Congenital Spondylolisthesis.—Spondylolisthesis is the term used to designate the condition of forward displacement of the body of the fifth lumbar vertebra with relation to the top of the sacrum. As a rule only the lumbo-sacral articulation is involved, and the fifth lumbar vertebra with the superimposed spinal column moves forward as a whole. Congenital and traumatic types are recognized. The former is due to defective development of the spinal arch, as is well shown by Adams's specimen, in which there was a failure of fusion between the posterior spinal arch bearing the articular processes and the vertebral body. With such a condition, the body of the vertebra is deprived of the bony support, which normally holds it in position, and is entirely dependent upon the ligaments. The latter are not strong enough to withstand the tendency of the vertebral column to slip forward and downward from the top of the sacrum under the influence of the body weight; yielding occurs and is accompanied by gradual forward displacement of the entire spine.

Traumatic Spondylolisthesis.— Practically the same condition may be produced by trauma, and in a considerable number of instances has resulted from relatively slight violence and without the development of paralysis or any other serious disturbances to suggest the severe nature of the injury. In consequence, these cases are seldom diagnosed until after the

[10] S. J. Mixter and R. B. Osgood, *Amer. Journ. Orth. Surg.*, Feb., 1910, p. 348.

lapse of several weeks or months, when the persistence of pain and disability leads to a roentgenological examination, and then the true condition is recognized. The exact nature of the lesion is in doubt, as no specimens representing the traumatic condition have been examined so far as we are aware, and it is necessary to rely upon the roentgenograms for

FIG. 455.—Spondylolisthesis. Roentgenogram showing fifth lumbar vertebra displaced forward and downward from the top of the sacrum.

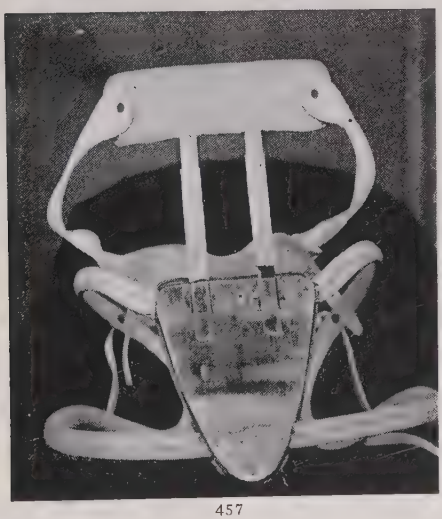
a knowledge of the condition. These do not help as much as might be expected, because of the deep situation of the fifth lumbar vertebra, the multiple overlapping shadows, and the absence of clear detail. Darling and Kleinberg [11] consider it a true dislocation, but it is possible that certain of the cases represent fracture-dislocations, the fracture involving the pedicles or articular facets, or it may be that developmental anomalies are present, which facilitate the dislocation.

Occurrence.— The injury is occasioned by accidents which produce forcible hyperflexion of the spine, such as a blow on the back of the

[11] S. Kleinberg, *Archives of Surg.*, July, 1921, p. 102.

neck or a force acting on the shoulders when the patient is in a stooping attitude. In one of the writer's cases it resulted from a fall on the back of the neck when wrestling, and in another from the sudden backing of a vehicle which the patient with his body bent and his muscles set was trying to push forward. In both of these cases severe pain was felt

456

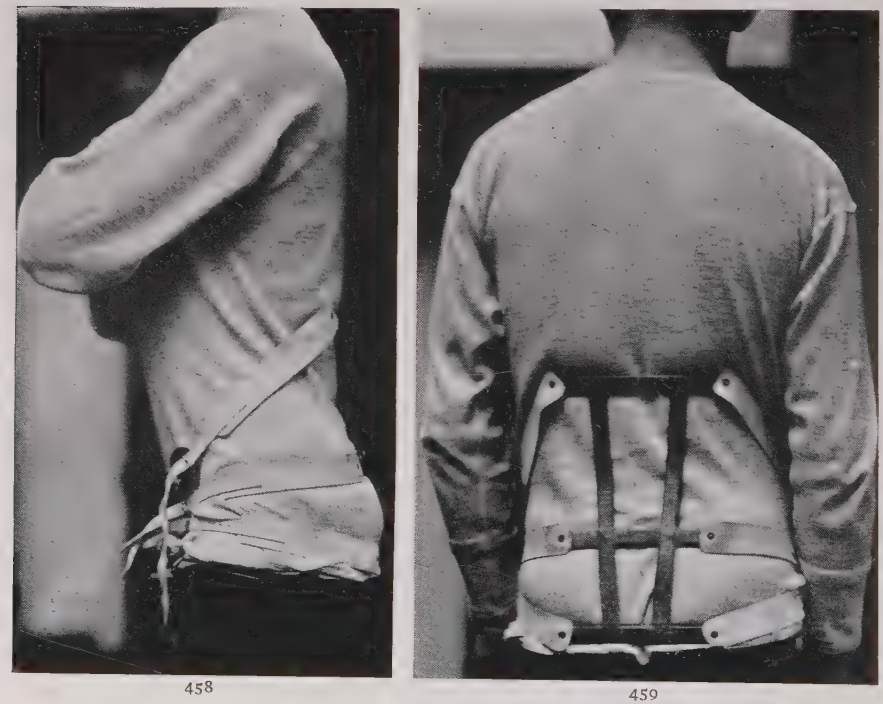


457

FIGS. 456 and 457.—Types of braces used in the convalescent treatment of fractures of the spine.

immediately in the low back, but both were able to walk, and neither remained recumbent for more than a few days. In one, sciatic pain from involvement of the fifth lumbar nerve root was a symptom, but in the other there was no evidence of nerve disturbance. Weakness of the leg muscles and paralysis of the peripheral nerve type have been present in certain of the reported cases.

Diagnosis.— In the late stage the appearance is fairly characteristic. The patient stands with the knees slightly flexed and the pelvis tipped backward, so that the sacrum is more vertically situated than normally. The upper portion of the sacrum is unusually prominent, and there is an abnormal hollow in the lumbar region above it. The trunk seems abnormally short as if it had telescoped into the pelvis. On palpation of the spinous processes, a depression is felt above the upper sacral spine, and



458 459

FIGS. 458 and 459.—Short back brace applied. Lateral and posterior views.

the spinous process of the fifth lumbar cannot be located. The roentgenological appearance is typical. In the antero-posterior view the body of the fifth lumbar appears rotated on its transverse axis, so that its superior surface faces forward in contrast to the rest of the spine, which appears normal (Fig. 455). The lateral view shows the body of the fifth lumbar projecting forward and downward in front of the sacrum.

Treatment.— Reduction of the fresh injury has not been attempted so far as we are aware, and to accomplish this by other than operative means would seem out of the question. As the condition, if untreated, results in an increasing amount of disability, this procedure would seem justifiable if the case were seen early enough after injury to warrant hope of success. The late results of the unreduced injury are bad on account of

secondary arthritic changes and postural alteration, the latter resulting in marked forward stooping of the shoulders and dorsal kyphosis, so that the patient must walk with a cane. In late cases some form of permanent fixation is required, such as a leather or steel brace, or, if the individual is in good general condition, a fusion operation should be advised according to the methods of Hibbs or Forbes to secure a bony ankylosis between the fourth and fifth lumbar vertebræ and the sacrum. Even when operative fixation has been secured, the use of a brace or jacket should be continued for a period of six months.

IV. ISOLATED FRACTURES OF THE SPINOUS PROCESSES OR LAMINÆ

Occurrence.—The spinous processes or the laminæ may be fractured either alone or in association with other vertebral injuries. The isolated

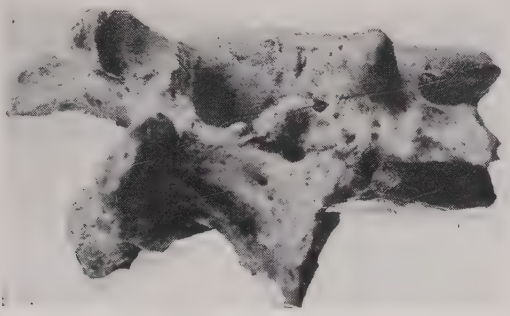


FIG. 460.—Isolated fracture of the pedicle of a vertebra. (Specimen from Army Medical Museum.)

type of fracture occurs usually as the result of direct violence, such as represented by a blow or a wound by a missile; very rarely a spinous process may be fractured by muscular action alone. Injury by firearms may occur at any level, but when due to other causes, the cervical region is the one usually affected, because of the superficial position of the bones and the relatively weaker type of structure. In the case of a blow, one or more of the vertebræ may be affected, but the ligaments and muscles usually prevent displacement of the bony fragments of sufficient extent to damage the cord. If both laminæ give way, however, the posterior arch may be driven in upon the cord, or an extra-dural hemorrhage may give rise to symptoms of pressure.

Diagnosis.—Clinically there is evidence of bruising of the soft parts, local tenderness over the spinous processes, and, in the event of displacement, the normal relation of the spines is disturbed. Crepitus and abnormal mobility may occasionally be recognized on palpation, but should not be sought for. Muscle spasm is a conspicuous feature. Roentgenological evidence of the nature of the lesion is essential in advising treatment, but the interpretation of the abnormality may be difficult.

Treatment.—In the event of symptoms of cord compression, immediate operation to elevate the depressed bone fragments may be indicated, this being one of the few cases in which general unanimity of opinion in regard to this procedure prevails. Irrespective, however, of whether

461

462

FIGS. 461 and 462.—The Bradford frame and its preparation. (461) The frame is made of gas pipe. (462) This is covered with two pieces of canvas as shown; folded sheets being interposed as padding.

such treatment may or may not be advisable, fixation of the spine is necessary to meet the indications of the bony lesion.

If the injury is confined to the spinous processes, ambulatory treatment is possible, the required immobilization being obtained by a plaster jacket. If the lesion is situated in the cervical region, the jacket should be of the "Minerva" type (Fig. 454), and include the head; if it be in

the lumbar region, a preliminary period of recumbent treatment should be employed for two to three weeks, a plaster jacket being used which extends from the coccyx to the upper dorsal region (Fig. 471).

If the laminæ are involved, recumbent treatment for a period of six to eight weeks is necessary. During this stage, fixation is best secured by means of a plaster of Paris bed or shell. This is made in two sections, one for the anterior, and one for the posterior portions of the body

FIG. 463.—The Bradford frame and its preparation. The frame is placed on the bed, being supported at the two ends by wooden blocks.

(Fig. 499). Ordinarily, the patient lies on his back in the posterior shell with the anterior section removed. Twice a day, however, the front portion is applied and secured with buckle straps, and the patient is then turned on the face, lying in the anterior section, while the posterior half is removed. In this way the back may be inspected and cared for, and danger of pressure sores is avoided. If there is a wound which requires dressing, ample access to the region may thus be obtained. A Bradford frame is a great convenience and facilitates the nursing care (Figs. 461-463). At the end of eight weeks the patient may be allowed to be about, wearing a plaster jacket, which at the end of twelve weeks from the time of injury is replaced by a steel back brace (Fig. 456). Convalescence is usually uneventful in the absence of cord injury, and functional recovery should be complete at the end of six months.

V. ISOLATED FRACTURE OF THE TRANSVERSE PROCESSES

Occurrence.— In common with other spinal injuries unassociated with cord injury the more frequent use of the roentgen ray and improvements in roentgenological technic have revealed the fact that isolated fracture

FIG. 464.—Fracture of transverse processes of second, third, fourth and fifth lumbar vertebræ. (Fracture Service, M. G. H.)

of one or more of the transverse processes is a fairly frequent accident. The injury occurs almost exclusively in the lumbar region. In the cervical region the transverse processes are not well developed, in the dorsal region they support and in turn receive support from the ribs, in the lumbar region, however, they are slender and long and exposed to injury.

Mechanism.— Although this type of fracture may be the result of direct violence, there is a growing belief that this is a less common factor than

indirect violence due to muscular action, as pointed out by Davis.[12] The quadratus lumborum muscle arises from the posterior part of the iliac crest and the lumbar aponeurosis and is attached by tendinous slips to the tips of the transverse processes of the lumbar vertebræ and above to the last rib. Its action is to draw down or fix the last rib in respiratory movements, or to flex the lumbar spine laterally. If the thorax and pelvis are fixed by the action of other muscles and a blow is received in the flank in the region of the quadratus lumborum, strain is transmitted to the attachments of the muscle, and the resistance offered by the transverse processes being slight, one or more of them may be torn off, the fragments being displaced laterally.

Diagnosis.— The symptoms consist of pain in the flank, sometimes referred to the knee on the affected side. All movements are painful and limited, particularly lateral bending toward the unaffected side, and there is marked spasm of the muscles. A sign of considerable importance is the production of pain in the back by hyperextension of the hip, this being caused by the direct pull of the psoas muscle on the injured transverse processes. Tenderness on pressure over the damaged bone can also be demonstrated. Care is necessary in the interpretation of the roentgenogram in order not to mistake the ununited epiphysis of a transverse process (usually the first lumbar) for a fracture. Error is also possible due to asymmetry in the axes of the corresponding processes on the two sides and the sharp shadow sometimes cast by the psoas muscle as it passes over the bone. Another source of error is a rudimentary rib on what one takes for the first lumbar vertebra, but which is really the last dorsal vertebra.

Treatment.— Such cases may be treated by the ambulatory method, careful fixation of the spine and pelvis being obtained by a close-fitting plaster of Paris jacket, extending downward as far as the coccyx and upward to the cervico-dorsal region. The plaster should be carefully moulded to the buttocks and loins, the bony prominences being protected with felt pads (Fig. 471). The jacket should be applied with the patient recumbent, preferably on a frame which supports the low spine and prevents sagging (Fig. 466). The jacket should be worn for four to six weeks, and may be split in front at the end of two weeks to permit removal for the purpose of baking and massage. Cases of multiple fracture should be kept recumbent for the first two weeks, but with a plaster jacket applied, as in the previous instance.

Prognosis.— Long periods of disability have been reported in many of these cases, but this would seem to be more the result of associated ligamentous strain than bony injury. It should be remembered that

[12] G. S. Davis, *Surg., Gyn. and Obstetrics*, Sept., 1921, p. 272.

465

466

467

468

FIGS. 465, 466, 467 and 468.—Application of plaster jacket for spinal injuries. (465) Goldthwait's portable frame. (466) Frame arranged on table and boxes placed to support the upper trunk and lower extremities. (467) Patient in place on frame, the knees being slightly flexed to flatten the lumbar spine. (468) Sheet wadding has been applied and felt strips have been fixed at the upper and lower margins of the cast. Felt pads have been placed over the iliac spines. Note that the chest is elevated and the abdomen flat.

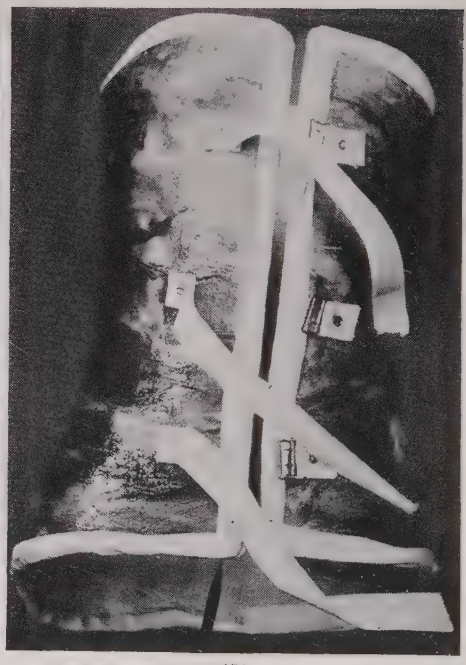
469

470

471

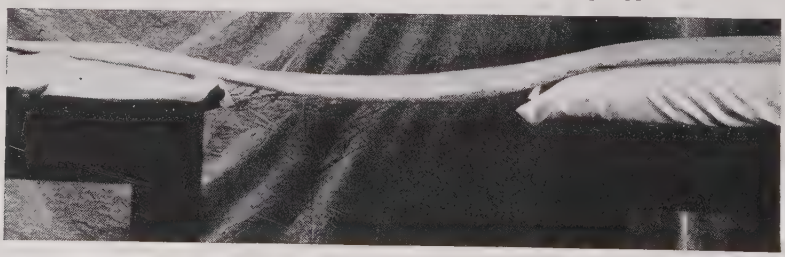
FIGS. 469, 470 and 471.—Application of plaster jacket for spinal injuries. (469) Plaster being applied. (470) Jacket completed, supporting irons being withdrawn from cast. Patient turned on side. (471) Jacket complete. Note that the chest is elevated and the abdomen supported.

472

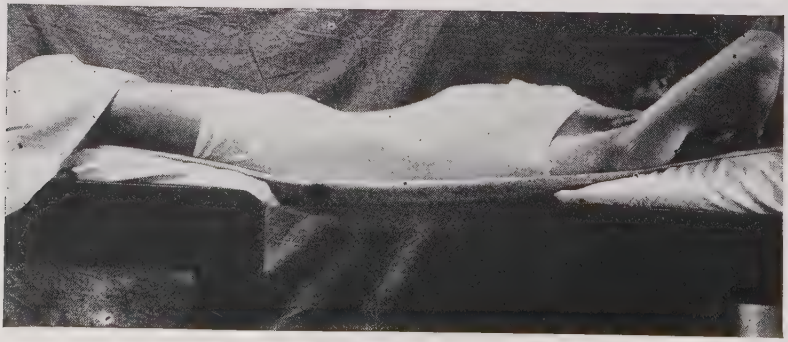


473

FIGS. 472 and 473.—Anterior and lateral views of removable plaster jacket. After drying, the plaster has been shellacked, the edges trimmed, and buckle straps applied.



474



475

FIGS. 474 and 475.—Application of plaster jacket. In the absence of a special frame, a sheet may be stretched between two tables to form a hammock as shown in figure 474. (475) The patient is then placed upon the hammock while the jacket is applied.

to the lay mind a fracture of the spine always represents a " broken back," and as such is associated with all manner of dreaded possibilities. Over-treatment is, therefore, particularly to be avoided. Union practically always results, and, although excision of the detached bony fragment has been practised in some cases, this would seem unnecessary from the experience of most surgeons and also from a consideration of the insignificant function of the process itself.

VI. COMPRESSION FRACTURE OF THE VERTEBRAL BODIES

Production.— The term "crush fracture" or "compression fracture" of the spine is used to designate an injury affecting one or more of the vertebral bodies which is characterized by impaction of the spongy bone, a crushing together of the upper and lower surfaces, and a mushrooming of the body so that its height is diminished and its width increased. It occurs more frequently than any of the other bony injuries of the spine and is produced usually by forcible hyperflexion or by a force acting in the long axis of the vertebral column when the latter is in a position of slight flexion. A fall of slate or rock on the shoulders from the roof of a mine is a common cause as is also a fall from a height on the buttocks, feet, or head. While it is usually produced by considerable violence, it is important to emphasize the fact that not infrequently it results from comparatively slight trauma, such as a fall in the sitting posture, and that the resulting injury may at first appear so trivial that its true character may not be recognized. The lower thoracic and upper lumbar vertebræ are the ones most frequently affected, but the reported cases include fractures at practically every level (Fig. 476). A fall on the feet or buttocks is more apt to cause injury in the lumbar region, while a fall on the head affects the cervical region more commonly.

Pathology.— The limit of elasticity of the vertebral body is reached in the area affected, and a crush fracture results. The spinal arch, being composed of compact bone, and the force being exerted on the anterior portion of the column, usually escapes injury. One or more of the bodies may be affected, in which case the intervening intervertebral disc is also involved. Usually the anterior portion of the body is compressed more than the posterior portion, so that on median section it appears wedge-shaped, the apex of the wedge pointing forward. The crush may be asymmetrical, so that one side is higher than the other, causing a lateral deviation of the spine at the point of injury. Isolated fragments of bone may be broken off, and one of these may project into the spinal canal, or the posterior common ligament may be torn, allowing the intervertebral disc to protrude, or there may be a bulging of the posterior portion of the body, any one of which accidents may cause symptoms of cord compression. As a rule, however, except in the case of severe trauma,

the cord escapes injury, but involvement of one or more of the nerve roots occurs more frequently. In Wallace's group of seventy-eight cases,

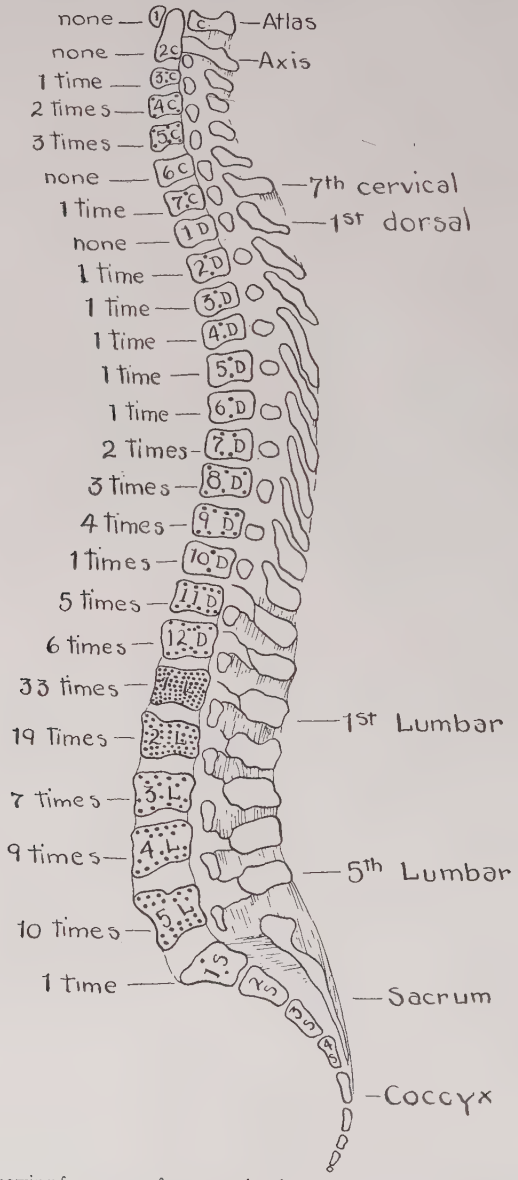


FIG. 476.—Diagram showing frequency of compression fracture, according to Wallace. 125 bodies involved in 82 cases. (:) Shows involvement of vertebra once. (::) Shows involvement of vertebra twice, etc.

paralysis was present in only twenty-three, or thirty per cent., and analysis of these figures shows that this complication occurs with much the greatest frequency in fractures involving the cervical region.

Clinical Features.—On account of the severe nature of the trauma which causes a large percentage of these lesions, it is not surprising to find that they are frequently associated with other severe injuries of the head, limbs, and internal organs, occasionally of fatal character. However, in contrast, it should again be emphasized that compression fracture may follow a comparatively mild form of violence. It is this fact, along with negative evidence of cord injury, which has made it possible for so many

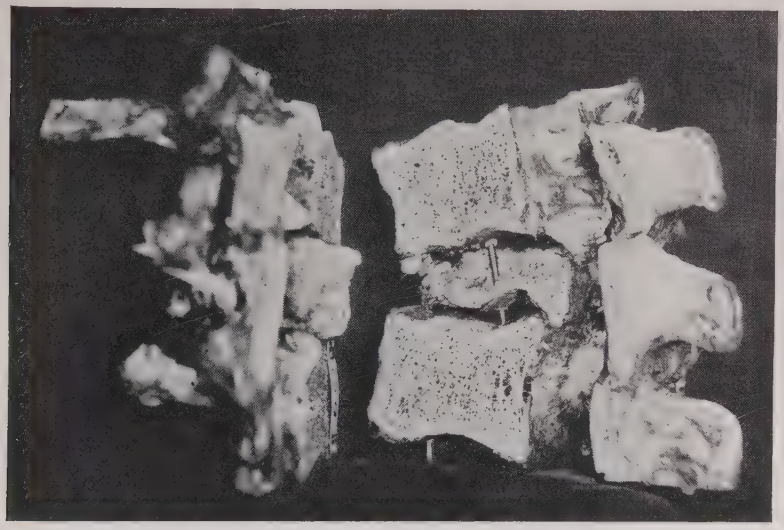


FIG. 477.—Specimen illustrating compression fracture. (Warren Anatomical Museum.)

cases to escape recognition. The importance of diagnosis lies in the fact that with continued use a traumatic spondylitis is set up, the deformity gradually increases, and the result may be permanent or prolonged disability.

Usually the presence of pain and deformity at once suggests an injury to the spinal column. The spine is angulated at the level of the lesion, and the sharp projection of the spinous processes produces a kyphos, the character of which varies depending upon the number of vertebræ involved, the amount of actual compression, and its situation. Thus it may be sharp or full and rounded. When situated in the dorsal region, it is more evident than when in the cervical and lumbar regions, where it may succeed only in obliterating the normal forward curves of the spine. Movements of the spine are all limited and painful, and the pain in the region of the fracture is increased by pressing downwards on the head and shoulders in the long axis of the column. There is muscle spasm and tenderness in the region of the fracture, and pressure on the spinous process of the injured vertebra (the one below the spinous process which forms the apex of the kyphos) is particularly painful. Neuralgic pain, disturbance of

cutaneous sensibility, and muscle weakness in the region supplied by one of the spinal nerve roots is of considerable significance and of aid in determining the level of the lesion.

Roentgenologic Examination.—Roentgenograms should be made in two planes, the antero-posterior ones being stereoscopic. There is little diffi-

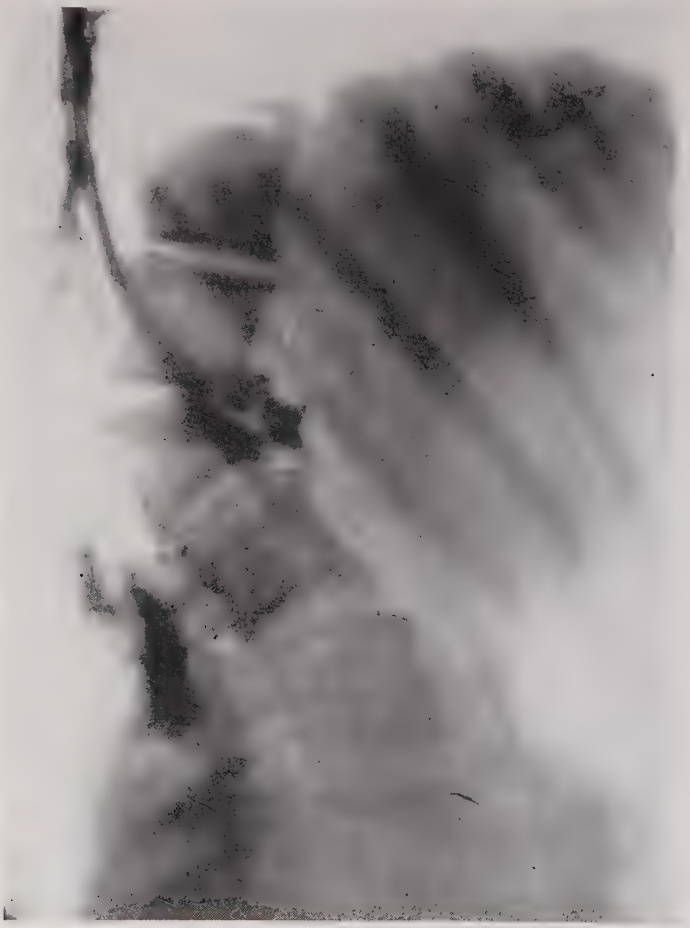


FIG. 478.—Compression fracture of the first lumbar vertebra. (Fracture Service, M. G. H.)

culty in recognizing the bony deformity, particularly in the lateral view. The appearance is very similar to that caused by tuberculosis of the spine unassociated with abscess and it has been mistakenly diagnosed as this condition on more than one occasion. In Pott's disease the intervertebral disc is involved early, while in fracture it is more likely to remain intact. Healing occurs by ankylosis of the injured vertebræ, and this is accomplished by the formation of large bony spurs beginning at the margins of the

bodies and extending upward and downward until they meet and fuse. When examined in the late stage of healing, this may lead to the diagnosis of hypertrophic arthritis.

Treatment.— Recumbent treatment is essential, with fixation of the spine by plaster of Paris. It seems logical to attempt correction of the deformity,

FIG. 479.—Compression fracture of the first lumbar vertebra. (Specimen from Army Medical Museum.)

particularly in the cases with evidence of nerve root injury, but we have yet to be convinced of the real effectiveness of any procedure yet advocated for this purpose. Most of the methods proposed aim to accomplish this by forced hyperextension of the spine at the seat of injury, various mechanical devices being used to provide a fulcrum at the apex of the deformity, combined with plaster fixation of the pelvis and spine. As a matter of fact, the key to correction of deformity is contained in the matter of correct diagnosis at the time of accident and the immediate institution of recumbent treatment, which prevents deformity from increasing. In cases so treated, the force of gravity is transformed from a deforming agent into a corrective one, and kyphos is never conspicuous.

Fixation.— Our own preference is, therefore, to treat such fractures in recumbency upon a two-section plaster shell or bed. (See Figs. 497, 498, and 499.) Great care should be employed to insure a close-fitting mould that properly supports the low back and lower ribs. The shell should include the head and neck and below should extend to the knees,

FIG. 480.—Lateral roentgenogram of the spine, showing compression fracture of the seventh dorsal vertebra. (Fracture Service, M. G. H.)

thus fixing the hips, without which solid fixation of the pelvis and lumbar spine is not obtained. When the fracture is in the cervical and cervico-dorsal region, extension should be applied to the head (Fig. 450); when it is situated in the lumbar spine, continuous traction should be applied to both legs by means of weights and pulleys. The care of the patient is the same as already detailed (p. 357). Ordinarily, the patient lies in the posterior shell on a Bradford frame (Figs. 461-463), with the anterior portion removed. At regular intervals, however, in order to relieve the back, and to care for the skin, the anterior section is buckled in place, the patient turned on the face, and the posterior section removed.

There is considerable discussion as to the length of time recumbent treatment should be employed, but we believe eight to ten weeks is sufficient for solid union. The patient is then allowed up in a plaster jacket, which, in case of injury to the cervical or upper dorsal spine, should be of the "Minerva" type to include and fix the head and neck (Fig. 454). This jacket is worn for six to eight weeks, and then, depending upon the

FIG. 481.—Old compression fracture of second lumbar vertebra. Note the callus formation.

location of the fracture, the patient is allowed to go without support (mid-dorsal), a back brace is worn (lumbar) of the type shown in figures 458, 459, or a Thomas collar is used (cervical or upper dorsal), as in figure 451. The period of disability should not extend beyond six months, and the progress of healing, which is accomplished by the formation of bony bridges uniting the injured vertebra to those above and below, should be followed by roentgenograms made at regular intervals.

Operative Treatment.—Of late, the advisability of treating compression fractures of the spine by the operative method with internal bone fixation has been much discussed. The more general employment of this procedure is advocated on the ground that it imitates nature's method of healing by ankylosis, that it is more certain in its results, and that the total period of disability is less than when the condition is treated by external fixation alone. On the other hand, there is a large group

482

483

FIGS. 482 and 483.—Old long-standing compression fracture of the sixth cervical vertebra with gradually developing cord symptoms. (482) Lateral view. Note narrowing of intervertebral space. (483) Antero-posterior view.

of surgeons, among whom the authors enroll themselves, who believe that with the early employment of complete fixative treatment, such as above outlined, and continued for a sufficiently long period of time, as good, if not better, results may be obtained as by the operative method, and with decreased risk. They believe that as long a period of external fixation is required following operative treatment as without it. By the conservative method, healing is accomplished by means of a minimum amount of ankylosis, whereas by operation it is necessary to fix an extensive area of the spine above and below the lesion, and this may later constitute a real cause for disability. Their feeling, therefore, is that conservative treatment should be employed in all recent cases, but that in the late cases which have had inadequate treatment, or when there is complaint of continued pain and weakness or increasing deformity (see Traumatic Spondylitis, below), operation to secure bony ankylosis may be definitely indicated. When operation is to be performed, the procedure used should be the one which secures the most solid and extensive ankylosis possible, that is, a fusion operation such as described by Hibbs [13] or Forbes,[14] rather than the simple insertion of a bone graft.

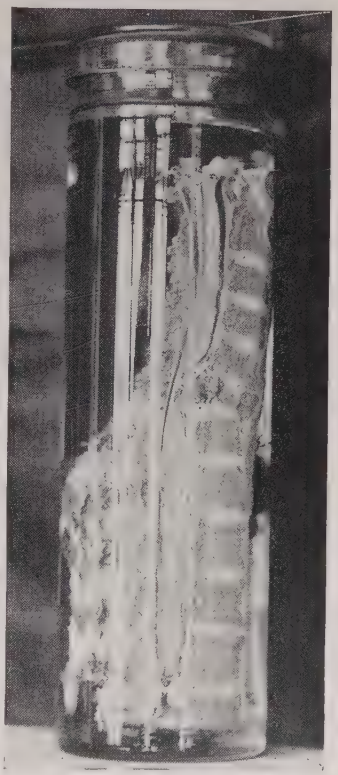


Fig. 484.—Compression fracture with compression of the cord.

TRAUMATIC SPONDYLITIS (KÜMMELL'S DISEASE)

Kümmell's Disease.— Kümmell[15] has drawn attention to a form of rarefying osteitis of the spine following injury to the back. It is probable that the condition represents only the late sequelæ of an undiagnosed compression fracture of the spine; at any rate it is particularly likely to develop after such an injury. It manifests itself after a period of symptomatic improvement by the development of pain and weakness in the spine and neuralgic and motor disturbances in the legs. Kyphotic deformity gradually appears, due to softening of the injured vertebræ and subsequent crushing from strain applied before the callus has had time to consolidate. If untreated,

[13] R. A. Hibbs, *N. Y. Med. Journ.*, May 27, 1911. *Journ. A. M. A.*, Oct. 26, 1918, p. 1372.

[14] A. M. Forbes, *Canadian Med. Asso. Journ.*, March, 1911. *Journ. Orth. Surg.*, Sept., 1920, p. 509.

[15] H. Kümmell, *Arch. f. klin. Chir.*, Nov. 24, 1921.

these phenomena tend to progress and may result in cord compression and paralysis.

Treatment.—The treatment consists of recumbency in a plaster shell on a Bradford frame, the position being one of hyperextension to correct the kyphotic deformity. After a period of six to eight weeks the patient may be allowed up with a well-fitting plaster of Paris jacket, which is later replaced by a leather corset or suitable back brace. However, our

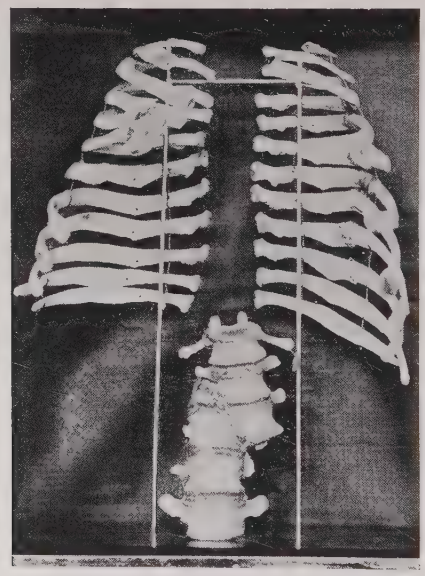


FIG. 485.—Fracture dislocation of the lumbar spine. (Specimen from Warren Anatomical Museum.)

own experience with conservative treatment is not very favorable, the symptoms tending to recur when the patient resumes an active life. For this reason, we are inclined to advise operative fixation of the spine by the Hibbs or Forbes fusion method as offering the quickest and most permanent solution of the difficulty.

VII. TOTAL DISLOCATION AND FRACTURE-DISLOCATION OF THE SPINE

Fracture-dislocation is to be regarded as one of the most serious lesions that can affect the spine, because of the frequency with which it is associated with complete and irreparable crushing of the cord. It is the injury popularly known as a "broken back," and the location of the lesion is usually in the lower thoracic or thoracico-lumbar region. Most of the cases met with occur in coal-miners or quarrymen from a heavy fall of coal or rock upon the bent shoulders, the body being in the stooping posture. The mechanism of its causation has been described at the beginning of the section.

Pathology.— Different forms of fracture-dislocation may occur, but the majority conform more or less closely to a single type, which consists of a complete bilateral dislocation of the articular facets forward, along with a fracture of one or more of the bodies of the vertebræ. The fracture-line in the body runs in oblique fashion from above and behind in a downward and forward direction and corresponds with the constant displacement of the upper fragment and the section of spine above it,

FIG. 486.—Fracture dislocation. Note fact that healing has occurred in spite of complete displacement. (Specimen from Warren Anatomical Museum.)

which pass downward and forward (Fig. 485). Examination of the specimen demonstrates that the cord is crushed between the posterior edge of the broken body below and the arch of the vertebra above. The displacement may be so great that the dislocated vertebra lies on the anterior surface of the undisplaced vertebra below (Fig. 486).

Other typical kinds of fracture-dislocation occur in a backward direction from hyperextension of the spine, but they are very rare. Sometimes the fracture-dislocation approaches in character that of a total dislocation when there is a pure dislocation forward and downward of the body of the upper vertebra with fracture of the articular processes. Total forward dislocation takes place in the cervical region.

Clinical Features.— Fracture-dislocation of the spine associated with damage to the cord lends itself readily to diagnosis from the history of the injury, an analysis of its method of causation, and the accompanying paralysis. On gentle palpation of the spinal contour, a solution in continuity is at once demonstrated in the shape of a clearly-defined, sharp,

backward projection of the spinous processes. The most prominent process is that of the broken vertebra, and the upper segment of the column having passed forward and downward, the spinous process next in series superiorly is felt to have been displaced forward. Pain is generally present at the site of fracture, increased by attempted motion or by local pressure. The roentgenogram demonstrates the exact nature of the injury. These cases must be handled with the greatest care lest further displacement of the fragments be produced with resulting increase in the damage to the cord. The whole clinical picture is, however, dominated by the symptoms of severe cord injury and the condition of shock, which is frequently associated with it.

Treatment.—The principles and details of treatment, in so far as the fracture itself is concerned, are the same as in cases of compression-fracture, namely, immobilization in a two-section plaster shell on a Bradford frame. Treatment of shock is the urgent indication and calls for elevation of the foot of the bed, application of heat, use of morphine in large doses, injection of normal salt solution by hypodermoclysis, or intravenously, and transfusion of blood in severe cases. Only when the patient has rallied from shock can it be a question of treatment of the fracture itself or of the cord lesion other than keeping the patient quiet in the recumbent position.

The question of whether laminectomy is to be advised or not depends chiefly on the neurological findings, and is discussed elsewhere under the heading of Injuries of the Spinal Cord. When gross displacement of one segment of the spine on the other is present, an attempt may be made by careful manipulation combined with traction and counter-traction to restore anatomic alignment. On account of the extensive tearing of ligaments and muscles which accompanies the injury, this has been accomplished in some cases, although not within the experience of the writers. In cases with complete paralysis, the most careful nursing attention is required with special reference to the care of the skin, bladder, and rectum. These points are discussed elsewhere (pp. 388-390).

VIII. INJURIES OF THE SPINAL CORD ASSOCIATED WITH FRACTURES AND DISLOCATIONS OF THE VERTEBRAL COLUMN

PATHOLOGY

Causation.— Injury of the spinal cord may occur in association with any fracture or dislocation of the spine, but it is produced with the greatest frequency by lesions of the more severe type, those which affect the integrity of the spinal column as a whole or which are accompanied by considerable displacement. The cord may be bruised, crushed, lacerated, or severed either completely or incompletely. The damage may be inflicted

by vertebral displacement of either permanent or temporary character, in the latter case, occurring only at the moment of injury, or there may be pressure by indriven fragments of bone, or the cord may be stretched across a bony projection or knuckle. Such injuries vary from minute lesions

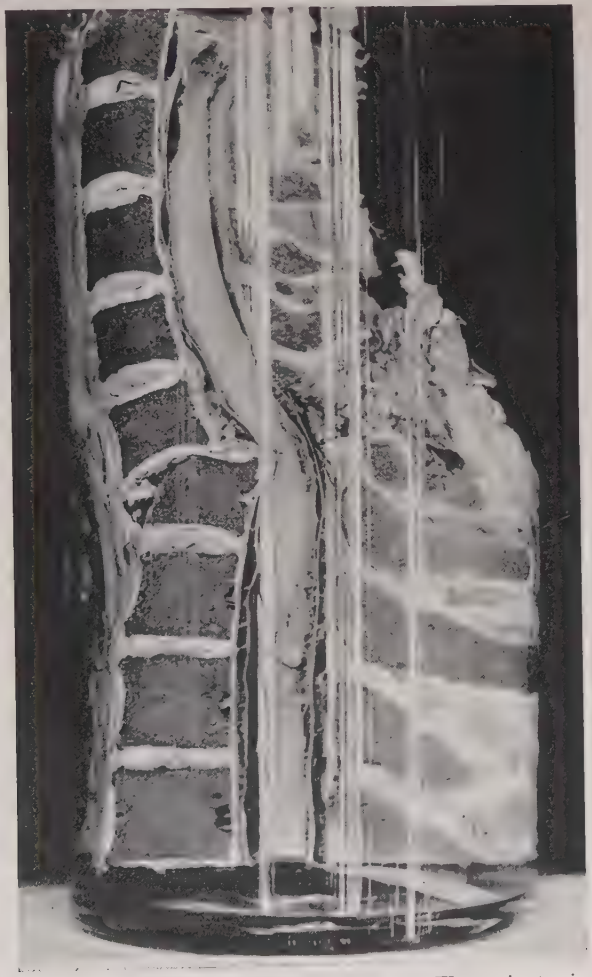


FIG. 487.—Fracture dislocation of the spine. (Specimen from Warren Anatomical Museum.)

barely discernible on the closest study of the cut sections to gross conditions, such as complete division or pulpefaction of the cord substance.

Hæmorrhage.—Hæmorrhage of greater or less degree accompanies these injuries and may be extradural, subarachnoid, or intramedullary in situation, depending upon the type of injury. Extradural hæmorrhage may of itself cause compression of the cord as a result of a rapid localized accumulation of blood. Subarachnoid bleeding, unless from a large ves-

sel, is not apt to be immediately harmful, as the space is large and the blood tends to settle below the level of the cord. Later, as a result of contraction and organization of the clot, some of the nerves of the cauda equina may be compressed, and symptoms of root pressure develop. Intramedullary hæmorrhage is much more serious, as even slight extravasation of blood into the tissues of the cord cannot occur without destruction of fibres and nerve cells. The hæmorrhage frequently involves the gray matter, extending up and down the cord over a distance of several segments, or it may take the form of multiple small hæmorrhages scattered diffusely through a small section of the cord.

Secondary Changes.— In addition to causing immediate local effects, practically every injury of the spinal cord gives rise to secondary changes which are the result of impact or a part of the reaction to trauma. Thus, œdema, circulatory disturbances, and formation of small cystic cavities occur in the immediate neighborhood of the lesion, and œdema of both gray and white matter, with swelling and softening of the cord, may be found at a considerable distance from the seat of injury. These disturbances are of importance because they explain why function may be altered in certain tracts of the cord which are not actually involved by the injury. When there is much comminution, or crushing of the body of the vertebra, the nerve roots are likely to be involved. These root lesions may be widely spread even when the bony injury is sharply circumscribed, and in such case they are produced by subperiosteal hæmorrhage and swelling rather than direct injury.

DIAGNOSIS

From the large number of factors which enter into the production of cord lesions, it will thus be seen that great variability may be expected in the symptomatology of different cases, even with the same type of vertebral injury. The neurologic examination reveals only the state of the cord with reference to function, but offers no sure means of determining the extent of actual damage. Destructive lesions and physiologic ones coexist to varying degrees in every injury unless there is complete division of the cord, and there is no positive way of differentiating between the part that is of functional character and the part that is not. The character of the vertebral injury sheds no certain light on the extent of the nerve lesion, because of the occasional diffuse involvement of the cord from a spinal fracture of slight extent or *vice versa*. In incomplete cord injuries secondary changes may occur with alteration or modification of the clinical findings. In apparently complete lesions very considerable improvement may take place, due to absorption of exudate, subsidence of œdema, and the cessation of circulatory changes. Each case must be studied on its own merits, and the clinical findings analyzed in an effort to determine

the extent of the damage and its location. All possible data must be collected, and while the examination of the spine, the neurological evidence and the roentgenological findings by themselves give only an imperfect idea of the actual state of affairs, when combined, particularly if they all point in the same direction, permit at least a deduction as to the probabilities.

LUMBAR PUNCTURE

Subarachnoid Bleeding.—Lumbar puncture may yield information of considerable importance and should be performed in all cases of cord injury. The information to be obtained in traumatic conditions is chiefly of importance as it bears on two points, *viz.*, subarachnoid hæmorrhage and block-

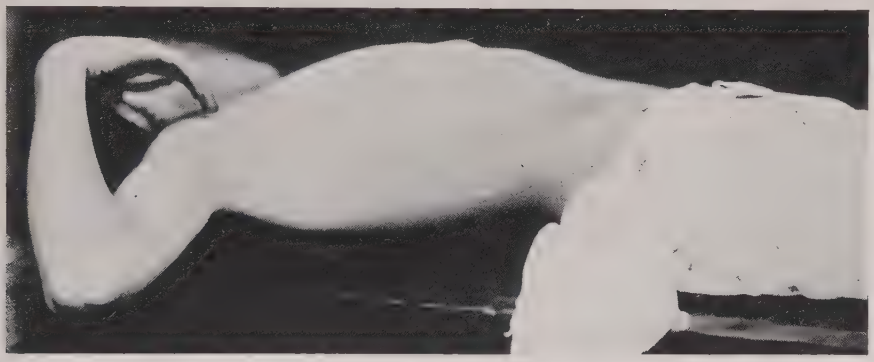


FIG. 488.—Position assumed by the arms in cord lesion at the sixth cervical segment.

ing of the subarachnoid pathway to the free circulation of the spinal fluid. Evidence of subarachnoid bleeding is obtained by the demonstration of uniform bloody discoloration of the spinal fluid. The determination of this condition is important, because when present, the repeated withdrawal of spinal fluid by frequent puncture is indicated in order to relieve pressure and rid the canal of blood. Blocking of the subarachnoid space in traumatic conditions with cord injury indicates presumably the presence of a displaced fragment of bone or an extradural hæmorrhage pressing on the cord.

Evidence of subarachnoid bleeding is obtained by collecting the escaping spinal fluid in several different tubes. If the tinge is the same in all, this indicates that the blood is actually mixed with the fluid in the subarachnoid space, rather than a local contamination from the accidental perforation of a vein by the needle.

Subarachnoid Block.—Combined lumbar and cistern puncture, according to the method of Ayer,[16] is necessary for the accurate determination of subarachnoid block, but few are sufficiently experienced in puncturing

[16] J. B. Ayer, *Journ. Bone and Joint Surgery*, Jan., 1923, p. 18.

the cisterna magna to venture on this procedure. Fortunately, it has been shown by Ayer that information of considerable value can be obtained from lumbar puncture alone if it be performed with proper technic. The tests are of three kinds, colorimetric, hydrodynamic, and chemical.

The colorimetric test is of little value in traumatic conditions, as the fluid is so frequently contaminated with blood that the yellow or xanthochromic color, which is characteristic of cord compression, may not be noted.

The hydrodynamic test depends upon measurements of the spinal fluid pressure under different conditions. A simple glass manometer of 2 mm. bore is used, which can be connected directly with the needle. The first reading is taken before any considerable amount of fluid has escaped. The presence or absence of the normal pulse and respiratory oscillations should be observed, the former being diminished or lost in block, while the respiratory oscillations are diminished in low block, but much increased in cervical or upper dorsal block. The effect of compression of both jugular veins on the pressure should be observed. Normally, this causes a sharp rise in the intraspinal pressure followed by a rapid decline when the jugular compression is discontinued. In case of block, there is no rise or only a very slight rise after a latent period. Lastly, 5-10 c.c. of fluid should be withdrawn and the effect on the pressure noted. When block is present, the pressure almost completely disappears upon the withdrawal of a small amount of fluid.

The chemical test depends upon the presence of an excessive amount of protein in the spinal fluid when there is cord compression. This is best demonstrated by the use of sulphosalicylic acid as a precipitant. Normally the protein appears as a barely discernible white cloud, but when present in excess, it appears as a massive white precipitate.

TOTAL TRANSVERSE LESIONS OF THE SPINAL CORD

Clinical Features.—The clinical features vary with the level of the lesion, but as a rule the patient, if he be conscious, and he usually is, notices that he is completely paralyzed below the level of injury and that all sensation has disappeared as well. The paralysis is complete, symmetrical, and of both motor and sensory character. The affected muscles are flaccid, and the tendon reflexes are lost. The upper limit of total anæsthesia runs horizontally around the body and is clearly defined. Immediately above it is a narrow zone of hyperæsthesia from irritation of the posterior spinal roots, and the patient notices this as a girdle pain, as if a band were tied tightly about the body. The level of anæsthesia corresponds to the segment of the cord involved, and this may be determined by reference to any of the charts showing the distribution of the spinal nerves. As the

cord segments lie at a higher level than the corresponding vertebræ, allowance should be made for this in localizing the actual lesion (Fig. 440).

Vasomotor and trophic disturbances are common. The cutaneous vessels in the skin of the paralyzed parts are dilated, and the local temperature is raised. This is also indicated by a tendency to priapism, except

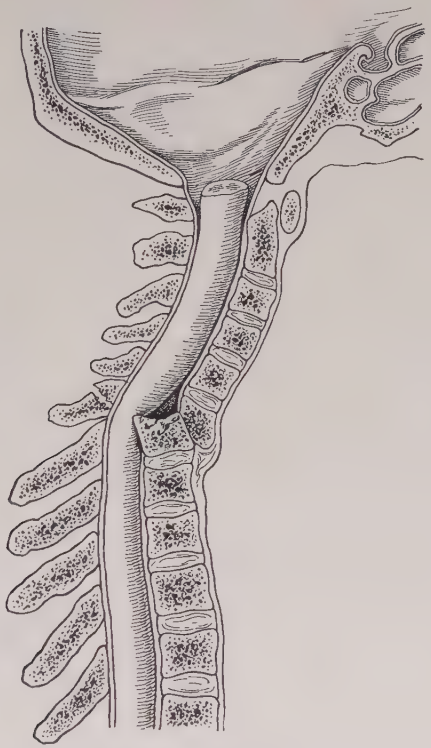


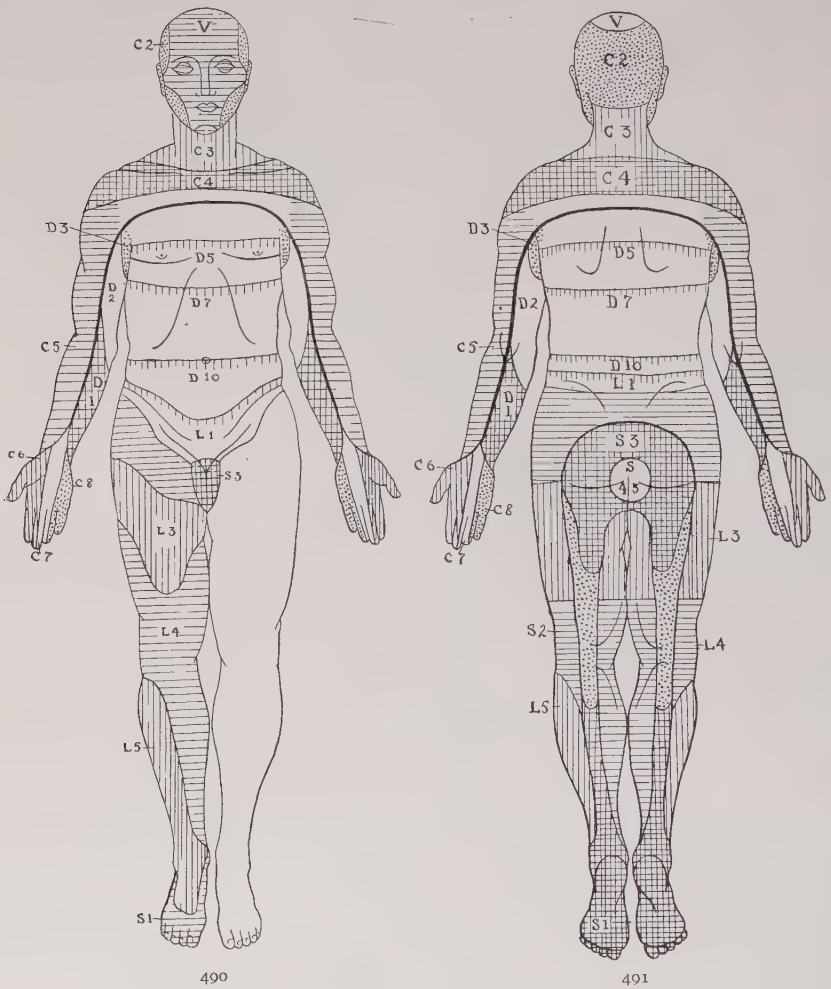
FIG. 489.—Fracture of the cervical portion of the spine with compression of the cord. Fracture is in the region of sixth and seventh cervical vertebræ. Complete lesion at this level would give rise to sensory and motor paralysis of the trunk and lower extremities, with partial paralysis of the upper limbs.

when the lesion is a low one. Of main importance is the liability to the occurrence of bed-sores in the region of bony prominences which are subjected to pressure, such as the sacrum, heels, elbows and scapulæ.

Bladder and Rectal Disturbances.—Disturbances of bladder and rectal functions occur in all complete lesions of the cord. These organs are controlled by centres which lie in the third and fourth sacral segments. Destruction of these centres by an injury affecting the first and second lumbar vertebræ or of their efferent roots at a lower level is accompanied by relaxation of the sphincters and incontinence of urine and fæces. If the lesion is situated above these centres, and either the afferent fibres in the posterior columns, or the descending fibres in the pyramidal tract

are involved voluntary control of these functions is lost, and there is retention of urine with overflow from a full bladder, and constipation.

Lesions of the Cervical Enlargement.— In the cervical region injuries usually affect the cord at its point of enlargement, which extends from the



FIGS. 490 and 491.—Figures illustrating the areas of cutaneous sensibility in relation to the segmental nerve supply. (After Jeliffe & White.)

fourth cervical to the first dorsal vertebræ. Usually, if the cord is extensively injured above this point, death results from paralysis of all the muscles of respiration. If the upper part of the cervical enlargement is involved, corresponding to an injury of the fifth cervical vertebra, all four limbs are paralyzed. The upper limit of anæsthesia is found at the second costal cartilage anteriorly, but posteriorly extends considerably higher.

There is recession of the globe of the eye, narrowing of the palpebral fissure, and contraction of the pupil from paralysis of the cervical sympathetic (C 8 and D 1). Respiration is carried on wholly by the diaphragm through the phrenic nerve (C 3, 4, 5). Such cases usually have a fatal termination within a few days from respiratory failure, due to an ascending myelitis. When the lesion occurs in the next lower segment, as from an injury of the sixth cervical vertebra, the muscles of the shoulders, causing abduction and external rotation of the arms as well as the flexors and supinators of the forearms, are unaffected, and the characteristic position is with the arms abducted and externally rotated at the shoulders, the elbows flexed, and the forearms supinated (Fig. 488). Sensation is normal along the radial side of the limb. With an injury of the seventh cervical vertebra, the next lower segment of the cord is involved, and, if the segments above this level are undamaged, the voluntary movements of the shoulders and elbows are preserved, but the small muscles of the hand are paralyzed, and there is anæsthesia in the distribution of the ulnar nerve and internal cutaneous nerve of the forearm.

Lesions in the Dorsal Region.—If the lesion is above the lower dorsal region, there is paralysis of the intercostal and abdominal muscles below the affected segment. The respiratory movements are imperfectly carried out, and there is difficulty in expelling mucus from the air passages, and not infrequently a hypostatic broncho-pneumonia develops and leads to a fatal termination. The paralysis of the abdominal muscles is reflected also in a tendency to gaseous distention of the bowel which further embarrasses respiration.

Lesions of the Lumbar Enlargement.—Injuries of the lower two dorsal and first lumbar vertebræ involve the lumbar enlargement of the cord. If it is the upper segment which is injured, the paralysis includes the legs and the lower abdominal wall, and the upper limit of anæsthesia is at Poupart's ligament. If the lower segment is involved, the paralysis extends from the knee down, and there is an area of anæsthesia which includes the legs below the knees and runs up the back of the thighs and also affects the region of the perineum, anus, scrotum, and penis. Paralysis of the bladder and rectum with incontinence is present in both.

Lesions of the Cauda Equina.—Injuries below the level of the first lumbar vertebra involve the cauda equina, and the effects vary in proportion to the number of nerves implicated. The paralysis may be complete or such nerve trunks as the femoral or obturator may escape. The central roots are the ones likely to be injured, in which case there is a saddle-shaped area of anæsthesia about the anus and posterior surface of the thighs. Pain is also apt to be severe, due to irritation of the roots. Sphincter paralysis is usual.

PARTIAL LESIONS OF THE CORD

Brown-Séquard Syndrome.— Complete hemisection of the cord gives rise to the classic Brown-Séquard syndrome. There is paralysis of the muscles on the same side of the body as the lesion with spasticity and exaggeration of the tendon reflexes, and often hyperæsthesia, while on the opposite or unaffected side, there is loss of tactile, pain, and temperature sense below the affected segment.

Irregular Lesions.— In partial cord lesions of irregular extent, there is much greater variability in the symptomatology. Often the picture is the same as in complete lesions, but it is possible to obtain a history that the patient moved one of the limbs following the injury or that the paralysis came on gradually instead of immediately. Usually the reflexes are increased instead of absent, or, if abolished early, return later and are exaggerated. The sensory disturbances are not so extensive as the motor paralysis, and the phenomena are apt to be different on the two sides. Bladder and rectal control are not completely lost.

Root Lesions.— Involvement of the nerve roots is characterized by disturbances of sensation and flaccid paralysis of muscle groups in the distribution of peripheral nerves and by lancinating or neuralgic pains referred to the area supplied by the nerves.

PROGNOSIS

An accurate prognosis is rarely possible in the first two weeks, and, indeed, any prediction as to the ultimate outcome is uncertain, because of the impossibility of knowing whether the symptoms are due to pressure without actual destruction of the cord elements and, therefore, susceptible to improvement on absorption of the extravasated blood and œdema, or whether actual destruction has been caused when a permanent residuum of paralysis must remain. The majority of cases present at first the picture of a complete transverse lesion, but recovery of greater or less extent is common.

Pseudo-recovery.— Riddoch [17] has pointed out that after a few weeks of flaccid paralysis, even in cases of complete division of the cord, there appears a stage of reflex activity. The reflexes are present and exaggerated, and movements of the limbs may be performed as a result of peripheral stimulation. In the past this has been regarded as evidence of partial recovery and has been a common source of error. Careful examination will show the reflex nature of such movements; for example, gentle stimulation of the sole of the foot calls forth a motor response in the direction of dorsi-flexion, which may spread to the other limb and more widely, in what is called a mass reflex, affecting the muscles of the

[17] Head, H. and Riddoch, G., *Brain*, 1917, Vol. 40, p. 217.
G. Riddoch, *Brain*, 1914, Vol. 40, 264.
G. Riddoch and E. F. Buzzard, *Brain*, 1921, Vol. 41, p. 397.

abdominal wall and causing evacuation of the bladder. Usually, in complete lesions, after a period of some months, the reflex centres become exhausted and their activity is lost. Return of the reflexes is not, therefore, necessarily an indication of recovery, but Riddoch finds that in incomplete lesions the reflexes differ from the typical mass reflex so characteristic of a complete lesion in being more purposeful.

Prognostic Value of the Reflexes.—Persistence of the plantar reflex or its early reappearance, if originally lost, or change from a flexor to an extensor type of response within the first week usually indicates that the lesion is incomplete and that some degree of recovery may be expected. Continued absence of the plantar reflex or persistence of the flexor type of response point to a severe lesion. Rapid muscle wasting and complete absence of muscle tone are in favor of a total lesion. The knee and ankle jerks are commonly lost in even mild lesions, so too much significance should not be attributed to their absence, although their early reappearance is a most favorable sign and is often followed by a large degree of recovery. Persistence of sphincter control or early return after primary loss indicates usually a mild type of lesion.

Mortality.—The prognosis is bad in the large run of cases, and in general the outlook is worse the higher the level of the lesion. Burrell [18] reported a series of 244 cases with a total mortality of 71 per cent., and Gurtt collected 277 cases with a mortality of 80 per cent. It is probable that under modern conditions these figures can be considerably bettered, as exemplified by Wilson's [19] series of 61 cases with a hospital mortality of only 40 per cent., likewise by the group of cases recently reported by Mixter [20] where the mortality was the same. A large proportion of the cases die soon after the infliction of the injury as a result of shock or from the effects of severe associated injuries, or within the first three weeks from the development of acute complications. Next to the danger from the injury itself or its immediate complications, the greatest menace lies in the development of cystitis and pyelonephritis, or extensive bed-sores.

Ultimate Prognosis.—Nevertheless, after the first three weeks the chances of survival for at least a considerable period are good even in the case of patients with complete transverse lesions. If the mentality and disposition are good, it is even possible for the patient to lead a fairly useful life. The writers know of a man with complete paralysis from a spinal injury who for many years has successfully conducted the affairs of a cigar and newspaper store from a wheel-chair, and thus earned a living for himself and family. Another case is that of a woman with a

[18] H. L. Burrell, *Brit. Med. Journ.*, October 27, 1894. *Annals of Surg.*, October, 1905.
[19] G. E. Wilson, *Canadian Med. Asso. Journ.*, November, 1911, p. 1054.
[20] W. J. Mixter, *Journ. Bone and Joint Surg.*, Jan., 1923, p. 21.

high dorsal lesion who has passed the last fifteen years recumbent on a Bradford frame and yet in spite of it has retained an alert, active mind, directed the affairs of her home, befriended neighbors, and all in all exerted a really remarkable influence on her own community.

TREATMENT OF SPINAL CORD INJURIES

The therapeutic considerations in spinal cord injuries differ depending upon the time that has elapsed since injury, and for the sake of convenience they will be discussed under the headings of immediate and remote treatment.

1. IMMEDIATE TREATMENT

Pathological Considerations Which Influence Treatment.— Aside from the treatment of the condition of shock, which when present is the urgent indication, the whole matter of immediate treatment in spinal cord injuries centres around the question of operative or non-operative treatment. The fundamental consideration in this connection is that the non-medullated nerve tissue of the spinal cord, if destroyed, does not regenerate. This does not apply to the spinal nerve roots or the structures forming the cauda equina, which are medullated and, therefore, capable of regeneration. From this standpoint it is important to realize that in case of complete severance of the cord or in severe crushing injuries which completely destroy its substance, no operative procedure offers hope of improvement and only superimposes a considerable operative risk in a person who has already suffered a nearly mortal injury. On the other hand, if the primary lesion is incomplete, there is always danger that hæmorrhage, swelling, and circulatory disturbances may with the lapse of time cause damage to the cord further and beyond that which was due to the original injury, and it is for the relief or arrest of this process that operative intervention at the earliest possible moment is urged. The wide opening up of the spinal canal by laminectomy removes at once one of the main factors in causing cord compression and at the same time offers hope of being able to afford further relief by removing depressed bone fragments, checking hæmorrhage, wiping out blood clot, or in the case of intramedullary hæmorrhage of incising the cord and producing an opening for the escape of blood or œdema.

Possibilities of Relief by Chordotomy.— In this connection the experimental work of Allen [21] is interesting. By dropping an object of known weight from a measured distance on the naked cord he succeeded in devising a traumatic procedure which, when applied to a group of animals, produced practically identical lesions in all. He then injured the cord in a series of animals by a force which previous experiments on a control group had shown was always sufficient to produce complete and perma-

[21] A. R. Allen, *Journ. Amer. Med. Asso.*, September 9, 1911, p. 878.

nent paralysis, but in the second series at varying periods after the original injury, he incised the posterior portion of the cord. He found that all the animals so treated ultimately recovered complete function, provided that the incision of the cord was not performed later than two hours after the primary injury. This experiment seems to show that chordotomy for the relief of swelling or hæmorrhage is of little avail unless performed within a period so short as to render its therapeutic application practically impossible. The work is suggestive and offers hope for the future, but it does not alter the general opinion that the only group of cases in which operative intervention is ever indicated is that in which the cord lesion is incomplete.

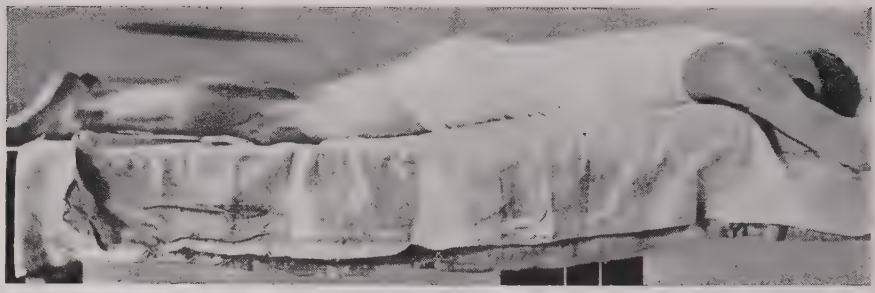
Differentiation of Complete and Incomplete Lesions.—However, when we turn to the means of differentiating complete and incomplete lesions, then we find that with our present diagnostic methods, this is only possible to a very limited extent. Many cases with complete motor and sensory paralysis and abolition of reflexes go on to complete ultimate recovery. Many of these represent mild contusions, transient compressions, or conditions of circumscribed hæmorrhage, or œdema in which operation would have been useless, in fact, dangerous, from the well-intentioned endeavor to relieve conditions by the performance of chordotomy or equivalent damaging procedures.

On the other hand, the actual findings at operation and the results in cases subjected to laminectomy lead to discouragement as to its value. In a large percentage of cases, the lesion is either of severe and irreparable nature or incomplete, but offering no chance of a remedial procedure. The operation carries a fairly high death-rate, and the number of cases in which it has been followed by recovery is small. Even in these few good results, it is very doubtful how much the operation contributed to recovery, since almost the same results have accompanied the non-operative treatment.

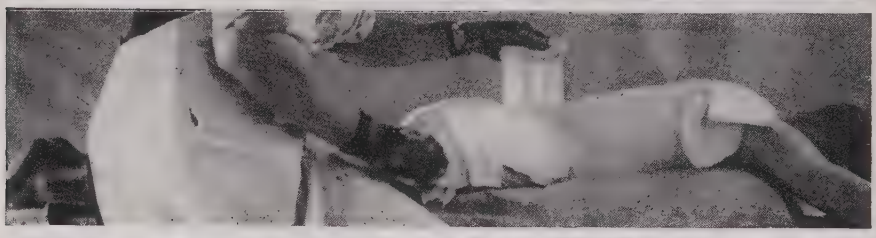
Clinical experience shows that any partial or incomplete lesion of the cord may be accompanied by so much hæmorrhage and exudation into the injured portion that it causes symptoms at first of complete interruption as if the cord had been completely pulpified or severed. On the other hand, any lesion of the cord of such slight degree as to cause only incomplete interruption of the conduction is by the same token likely to be so minute that operative interference is not apt to improve it, and the chances of complete recovery are in any case great without it.

Indications for Operative Interference.—The matter of deciding for or against operation is, therefore, debatable ground where the scales will be tipped one way or the other largely by the individual leaning of the surgeon in charge, his interpretation of the clinical findings, the facilities available, and the condition of the patient. The number of cases which can be

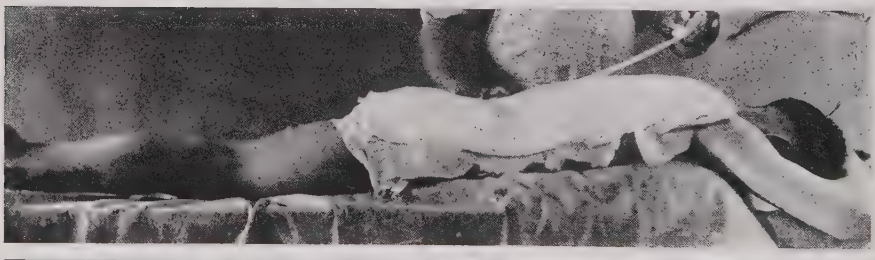
492



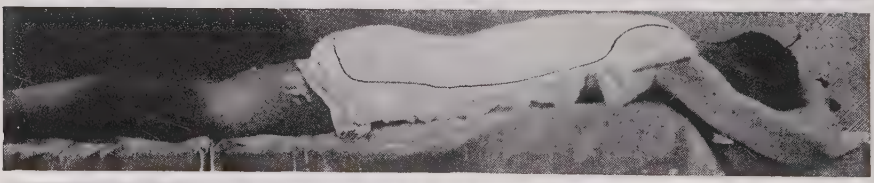
493



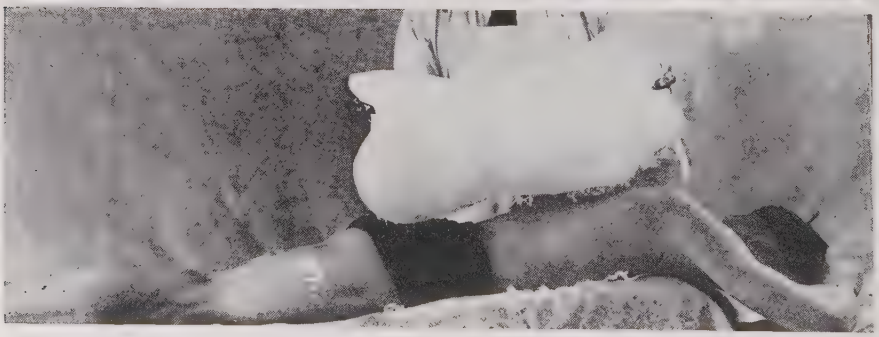
494



495



496



FIGS. 492, 493, 494, 495 and 496.—Application of plaster shell. (492) The patient is placed face down upon a pillow, a light undershirt being used to protect the skin. (493) Plaster bandages are unrolled backward and forward, forming a coating of plaster. Some of the layers are transverse. (494) Some are longitudinal. (495) When the plaster has hardened, the edges are marked out for trimming. (496) Completed shell after trimming.

helped by operation is undeniably small, and the question really is whether we will doom these few in order to avoid the possibility of harming others, or whether, in an endeavor to benefit an exceedingly small group, we will subject another larger group to operation unnecessarily. If it were possible for all surgeons to have the special experience and skill of a few who devote their entire attention to this field of surgery, then we would certainly favor operative interference in a considerable number of cases, but lacking that particular skill and extensive experience, we are strongly of the opinion that, by and large, conservative treatment is the least dangerous procedure and the one that in the long run will show the largest percentage of good results. The only cases we would except from this opinion are those in which careful and repeated examination within the first six to eight hours shows definite progression in the neurologic disturbances, indicative of gradually increasing compression of the cord, or those in which roentgenological examination demonstrates either depression of bone fragments from the posterior spinal arch or in case of a gunshot wound the presence of a foreign body in the spinal canal. Such cases should be operated upon at the earliest possible moment permitted by the patient's general condition. Operative treatment is also indicated in injuries of the cauda equina, but since this falls within the category of surgery of the peripheral nerves, operation may well be delayed until a later period when all possible improvement has been obtained or a decision is possible as to the extent of the actual damage.

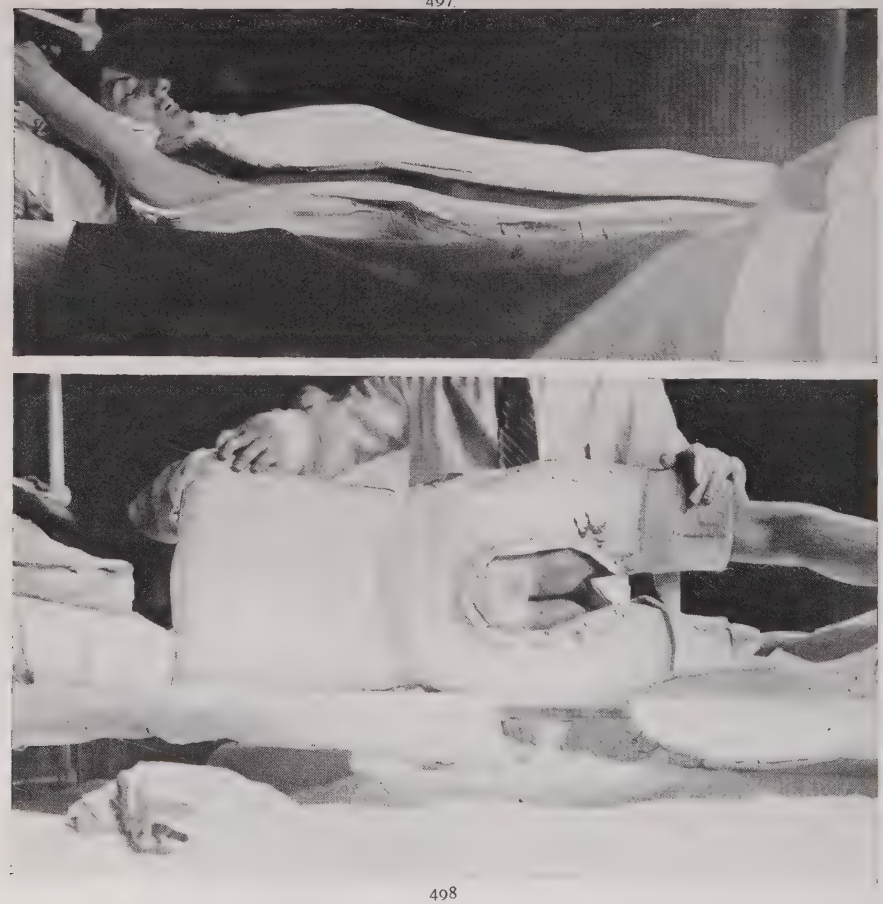
Non-operative Treatment.—The adoption of the non-operative plan of treatment as contrasted with the operative method does not mean that cases of vertebral injury with spinal cord involvement should be left entirely without treatment. Of itself, complete fixation of the spine offers a means of influencing the cord injury to a considerable extent. It prevents additional injury to the cord from the movement of bone fragments, which is often a factor of considerable importance. Immobilization also favors the cessation of bleeding and tends to limit the development of extensive secondary changes and hastens the absorption of the products of inflammation.

Fixation.— All cases of spinal cord injury, including those subjected to the operation of laminectomy, require immobilization in the recumbent position. Fixation is best obtained by the use of a two-section plaster bed placed on a Bradford frame, as previously described (Figs. 497-498). This should include the head and neck, and extend downward as far as the knees, supporting the back of the thighs, with an ample opening in the anal region to permit the use of the bed-pan without soiling. The plaster should be smoothly padded with piano felt. If the cervical region is involved, head traction should be employed, the upper portion of the

head piece of the cast being cut away sufficiently to permit its use. If the lumbar spine is the region affected, traction should be applied to the legs.

The application of the plaster bed involves turning the patient on his face and a certain amount of manipulation, which may not be wise in

497



498

FIGS. 497 and 498. Turning patient in the plaster shell. (497) The anterior half is applied and strapped in place. (498) The patient is then turned on the face, and the posterior half removed.

the first day or two after injury. Under such circumstances the patient should be immediately placed on a well-padded and properly-fitting Bradford frame (Figs. 461-463), with an opening in the region of the buttocks, which permits the use of the bed-pan without soiling of the skin.

2. REMOTE TREATMENT

Care of the Skin.—Because of the liability to the development of bedsores, the care of the skin is of great importance. Prevention is better than cure, and careful inspection of all parts twice a day, looking for

areas of redness, will often allow the removal of points of pressure before actual necrosis has occurred. In this connection it should be emphasized that the use of hot water bottles is dangerous and should be avoided. Because of the lack of cutaneous sensibility and the tendency to trophic disturbances, burns result very readily and may be of disastrous character. At regular intervals each day and for considerable periods, the patient should be turned so that he lies in the prone position on the anterior half of the shell, and the pressure on the back is relieved. The skin should be thoroughly bathed, rubbed with alcohol, and powdered at frequent intervals; above all, it should be kept clean and dry.

Bed-sores.— During the flaccid stage of the paralysis, the vitality of the skin is at a very low ebb, and it is at this time that bed-sores of the

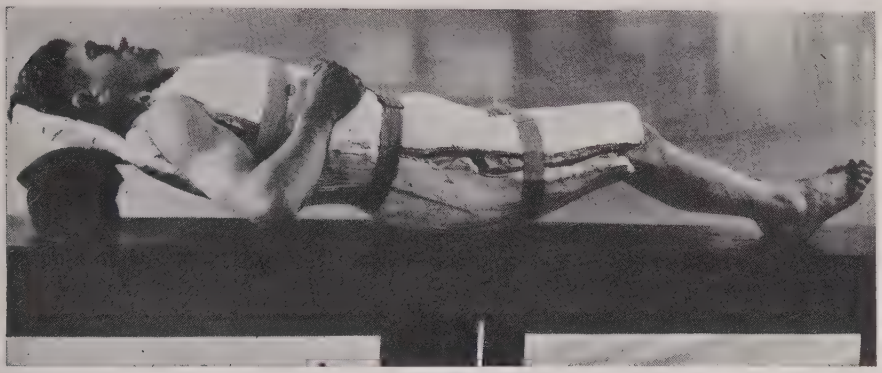


FIG. 499.—Anterior and posterior shell.

acute variety are most liable to develop. After the lapse of several weeks the nutrition of the skin improves from dilatation of its vessels, and sloughing occurs less readily. However, in spite of the greatest care, bed-sores may develop. When this occurs, they must be treated on general surgical lines, and healing, although slow, may eventually be expected. Pressure on the region should be removed, and during the sloughing stage the wound may be dressed with gauze moistened with Dakin's solution. When the necrotic material has separated, the wound may, with benefit, be exposed to the solar rays as frequently and for as long periods as possible.

Care of the Bladder.—Proper care of the bladder is also of fundamental importance. If there is retention of urine, catheterization with most careful attention to asepsis should be performed at regular intervals and frequently enough to avoid overdistention of the bladder, as this condition is conducive to the development of cystitis. However, a certain amount of infection always results, no matter what precautions are taken, and at the first sign of cystitis a permanent indwelling catheter may be introduced to provide constant drainage, and the bladder washed out daily with boric

acid or weak silver nitrate solution. Indeed, the development of urinary infection is so much a foregone conclusion that many authorities advocate continuous catheter drainage from the very beginning. Others advise suprapubic cystotomy in case of cystitis for the purpose of obtaining more complete drainage and of avoiding some of the difficulties which may ensue from constant retention of a catheter. As a rule a self-retaining catheter of the Pezzar type will meet the requirements. Hexamethylamine should be given as routine to all patients requiring catheterization in doses of 30 to 60 grains daily, combined with sodium acid phosphate to acidify the urine. Watch should be kept for evidence of renal irritation, such as the appearance of red blood cells in the urine, and, if this develops, the administration of the drug should be stopped.

Re-establishment of the Bladder Reflex.—After a period of several weeks or months, in cases with lesions above the lumbar enlargement, the bladder reflex frequently becomes re-established, although voluntary control is lacking. There is a return to the infantile condition with periodic emptying of the bladder when it becomes sufficiently distended or in response to peripheral stimulation. It is possible to aid this by training the patient to make pressure on the bladder with his hands at regular intervals, while at the same time reflex contraction of the abdominal muscles is incited by strong stimulation of the plantar surface of the foot. The importance of this lies in the possibility of being able to finally do away with catheterization and its attendant dangers of cystitis and ascending infection of the kidneys.

Sphincter Paralysis.— When the lesion involves the lumbar enlargement of the cord and there is paralysis of the sphincters, the only care required is the placing of a proper receptacle to collect the urine and avoid wetting of the skin. It is wise to catheterize the patient at least once to make certain that the patient is indeed emptying the bladder completely and that the condition is not due to retention of urine and overflow.

Care of the Bowel.— With lack of voluntary control of the rectal sphincter and levator ani muscles, there is marked constipation. This necessitates the daily use of enemata to empty the rectum and mild laxatives to keep the intestinal contents moving.

Prevention of Deformity.—Deformities of the limbs develop with the lapse of time, particularly in complete lesions, and, if untreated, lead to obstinate contractures, which, in case of later recovery of some of the spinal functions, seriously interfere with the use of the part. Such deformities should be prevented by proper splinting, and the circulation of the muscles and the suppleness of the joints maintained by massage and mobilization when necessary. Toe-drop is particularly likely to occur on account of the influence of gravity. This may be prevented by the use of adhesive traction strips applied to the plantar surface of the feet and

suspension of these from an overhead frame by means of cords, weights, and pulleys in a position to secure right-angle flexion of the ankles and slight inversion of the feet. Flexion contractures of the hips, which may result in spontaneous dislocation from muscular action, may be prevented by continuous traction to the legs.

Convalescent Treatment.—In the later stages of spinal cord injuries, when union of the spinal fracture has been obtained, fixation is no longer necessary. At this stage the patient may be cared for on an air mattress or Bradford frame. The nutrition of the skin has sufficiently improved to render the occurrence of pressure sores unlikely, and a more active life may be enjoyed. A comfortable wheel-chair in which the patient may move about is essential. In cases with partial recovery, it may be possible by means of crutches and the tripod gait and by the use of appropriate braces to make the patient ambulatory. In others, when the element of spasticity causes deformity and difficulty in the use of the limbs, it may be advisable to perform the operation of neurotomy according to the method of Stoffel [22] to weaken the muscles chiefly responsible for the deformity.

[22] A. Stoffel, *Münch. med. Woch.*, Nov. 21, 1911. *Münch. med. Woch.*, Dec. 24, 31, 1912.

CHAPTER XI

INJURIES OF THE BONES OF THE FACE

I. FRACTURE OF THE NASAL BONES
II. FRACTURE OF THE MALAR BONE AND ZYGOMATIC ARCH
III. FRACTURES OF THE SUPERIOR MAXILLA
IV. INJURIES OF THE MANDIBLE

1. Dislocation of the Mandible
2. Fractures of the Mandible

GENERAL CONSIDERATIONS

The skeleton of the face is formed in part by the ethmoid, temporal, and sphenoid bones, which also contribute to the formation of the cranium. The remainder is composed of purely facial bones, the nasal, lachrymal, palate, inferior turbinate, malar, and superior maxillæ, which are all double, and the vomer and mandible, which are single. While any experienced surgeon who possesses a knowledge of the anatomy and surgical relations of the region is perfectly competent to treat the majority of injuries to which these bones are liable, at the same time it is desirable in certain cases to have the services of specialists in facial and oral surgery because of their greater knowledge of the details of treatment and their familiarity with special mechanical procedures, which may be of value.

The bones which suffer individual fracture most frequently are the nasal bones, the malar bones, and the bones of the upper and lower jaw. The others are more often damaged in a multiple fracture. Fractures of the bones of the face are frequently compound from the laceration of the skin or mucous membranes, but the rich blood supply and the free drainage usually prevent the development of serious infection. Also because of the extreme vascularity, these fractures tend to unite quickly, and consequently displacement must be reduced at once. The most serious sequelæ of unreduced deformity are facial disfigurement, nasal obstruction, limitation of the movements of the jaw and faulty mastication due to misalignment of the teeth.

I. FRACTURE OF THE NASAL BONES

Anatomy.—The skeleton of the nose is composed of two nasal bones and five nasal cartilages, the latter consisting of two upper, two lower and lateral, and one septal cartilage. The septal cartilage forms the antero-inferior portion of the septum; the vomer, the posterior portion; while the perpendicular plate of the ethmoid forms the antero-superior portion. The nasal bones are two small oblong plates lying side by side at the root of the nose and forming the nasal bridge. Each nasal bone articulates in the midline with its fellow of the opposite side, above with the frontal bone (the nasion), laterally with the nasal process of the superior maxillæ, and mesially with the perpendicular plate of the ethmoid. If the outline of the nasal bones is traced downward, their point of union with the nasal cartilages at the osseous anterior nares may

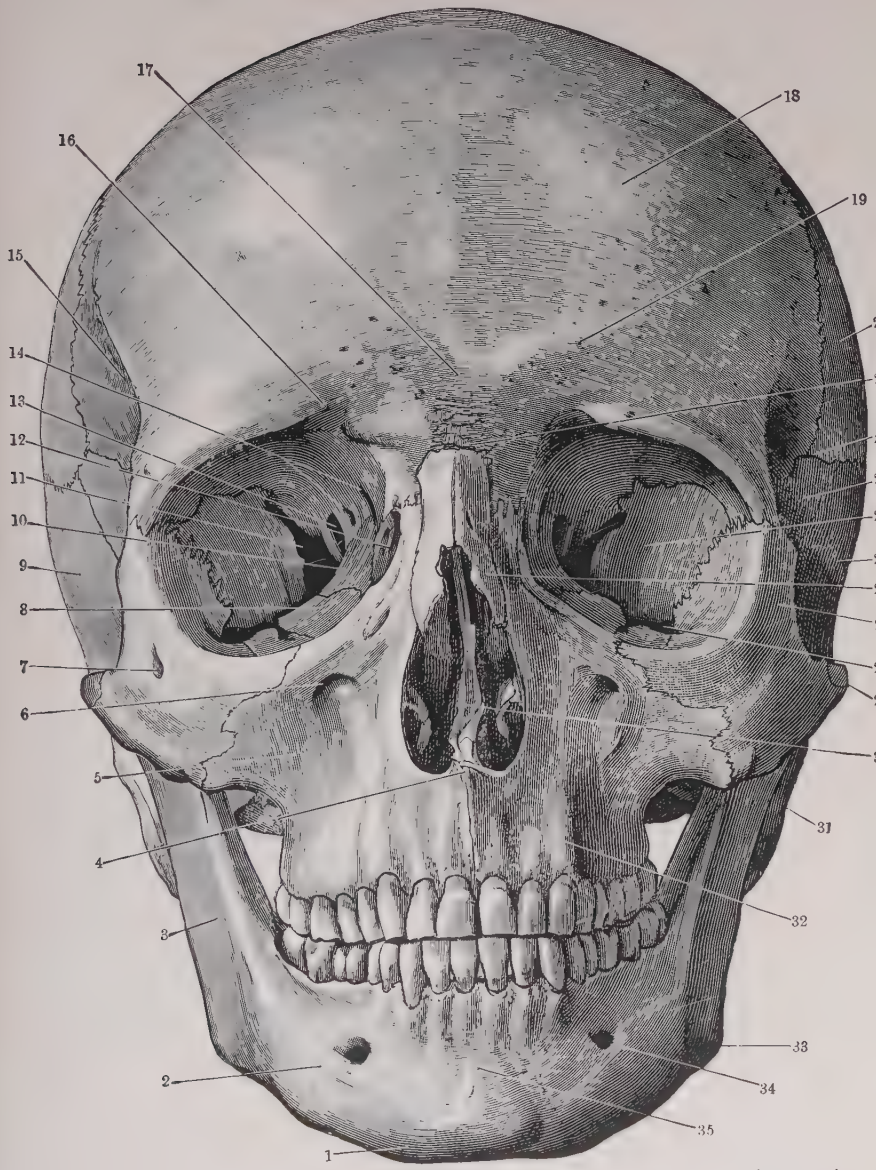


FIG. 500.—Anterior view of the bones of the face. (Cunningham: Text-book of Anatomy.)

1. Mental tubercle. 2. Body of mandible. 3. Ramus of mandible. 4. Anterior nasal spine. 5. Canine fossa. 6. Infra-orbital foramen. 7. Zygomatico-facial foramen. 8. Orbital surface of maxilla. 9. Temporal fossa. 10. Lateral surface of ethmoid. 11. Superior orbital fissure. 12. Lachrymal bone and groove. 13. Optic foramen. 14. Ethmoidal foramina. 15. Temporal line. 16. Supra-orbital notch. 17. Glabella. 18. Frontal tuberosity. 19. Superciliary arch. 20. Parietal bone. 21. Naso-frontal suture. 22. Pterion. 23. Great wing of sphenoid. 24. Orbital surface of great wing of sphenoid. 25. Squamous part of temporal. 26. Left nasal bone. 27. Zygomatic bone. 28. Inferior orbital fissure. 29. Zygomatic arch. 30. Apertura pyriformis, displaying nasal septum and inferior and middle conchæ. 31. Mastoid process. 32. Incisive fossa. 33. Angle of mandible. 34. Mental foramen. 35. Symphysis menti.

be readily recognized. The nasal chambers are narrow and their height rapidly increases as they extend backward from the anterior nares only to diminish again at the posterior orifices. The median wall of each cavity is formed by the septum, the mucous covering of which is firmly attached as a muco-periosteum. The lateral wall is formed by the

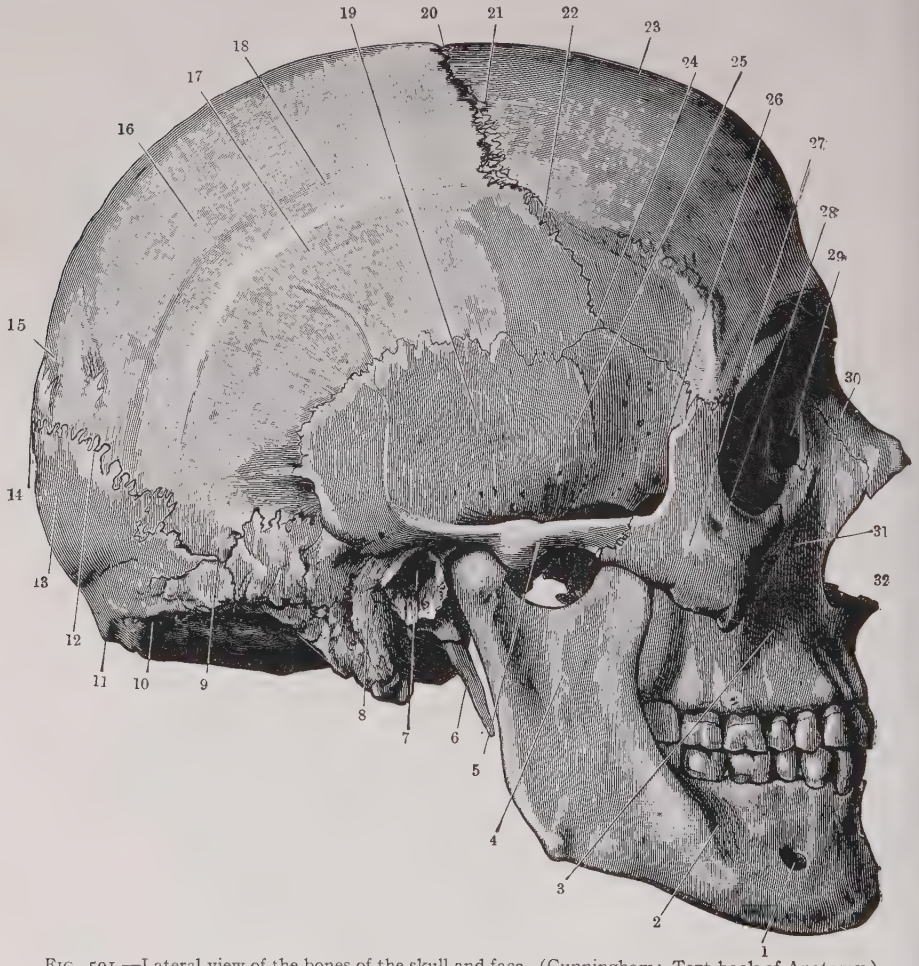


FIG. 501.—Lateral view of the bones of the skull and face. (Cunningham: Text-book of Anatomy.)

1. Mental foramen. 2. Body of the mandible. 3. Maxilla. 4. Ramus of mandible. 5. Zygomatic arch. 6. Styloid process. 7. External acoustic meatus. 8. Meatus process. 9. Asterion. 10. Superior nuchal line. 11. External occipital protuberance. 12. Lambdoid suture. 13. Occipital bone. 14. Lambda. 15. Obelion. 16. Parietal bone. 17. Lower temporal line. 18. Upper temporal line. 19. Squamous temporal. 20. Bregma. 21. Coronal suture. 22. Stephanion. 23. Frontal bone. 24. Pterion. 25. Temporal fossa. 26. Great wing of sphenoid. 27. Zygomatic bone. 28. Zygomatico-facial foramen. 29. Fossa sacci lacrimalis. 30. Nasal bone. 31. Infra-orbital foramen. 32. Anterior nasal spine.

superior maxilla and the ethmoid, and projecting from it into the nasal cavity are the three turbinates, which divide the chamber into the three meatuses. The naso-lachrymal duct opens into the inferior meatus. All of the accessory pneumatic cavities of the nose open into the chamber above the inferior meatus; the anterior and middle ethmoids, the antrum, and frontal sinus opening into the middle meatus, the sphenoidal cells into the roof, and the posterior ethmoid cells into the superior meatus.

Types of Fracture and Displacement.—Fracture of the bones of the nose is always due to severe direct violence, such as a blow or a fall. The level at which the bones are broken, the presence or absence of associated fractures of other bones, and the type of the displacement, all vary according to individual circumstances. Thus a fracture of the nasal bones may also involve the nasal process of the frontal bone and base of the skull, the nasal processes of the maxillæ, the bony or cartilaginous septum, or the lateral cartilages of the nose. The nasal bones are usually fractured near their point of junction with the nasal cartilages, the fracture line commonly being transverse, and there is apt to be depression and impaction of the fragments with some comminution. A fracture in this situation is apt to be accompanied by a bending, a fracture, or a

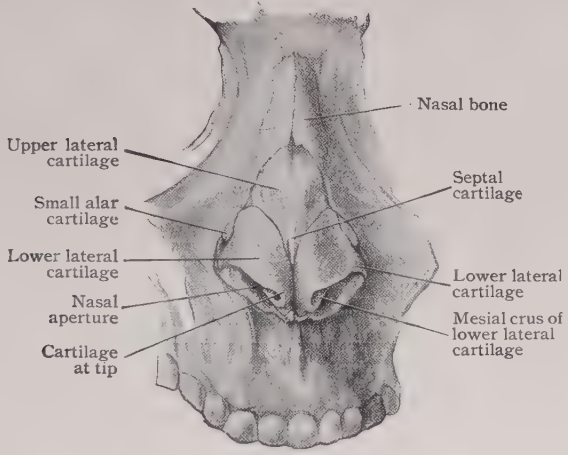


Fig. 502.—View of cartilaginous framework of nose. Anterior aspect. (Piersol: Human Anatomy.)

fracture-dislocation of the cartilaginous septum, the displaced septum bulging into one or the other nasal cavity.

If the force falls upon the upper part of the nasal bones, the fragments are usually comminuted and driven backward and occupy a position behind the nasal processes of the maxillæ. The perpendicular plate of the ethmoid may also be fractured in this event, and the nasal ducts may be injured. Occasionally, the septum alone is broken, and the nasal bones left intact, in which case the bridge of the nose is not flattened, and there is absence of external deformity. This may result in failure to recognize and correct the displacement, in which case considerable difficulty from nasal obstruction develops later. When the force is applied from the side the nasal bones may be dislocated from the nasal processes of the maxilla, with resulting lateral deformity. Lastly, the lateral cartilages may be dislocated from the osseous anterior nares or from each other.

Diagnosis.— The immediate effects are pain, swelling, deformity, epistaxis, and crepitus. Involvement of the accessory air sinuses results in a surgical emphysema when the patient blows the nose. The deformity takes the form either of a flattening of the bridge of the nose ("traumatic saddle-nose"), or of a lateral deviation. When the lateral cartilages are displaced from the nasal bones the deformity is situated at a lower level. The diagnosis is to be made by careful external examination and by inspection of the nasal cavities with the aid of a speculum and head mirror.

Treatment.— When displacement is present even to a slight degree, correction is indicated, as otherwise it results in disfigurement and nasal

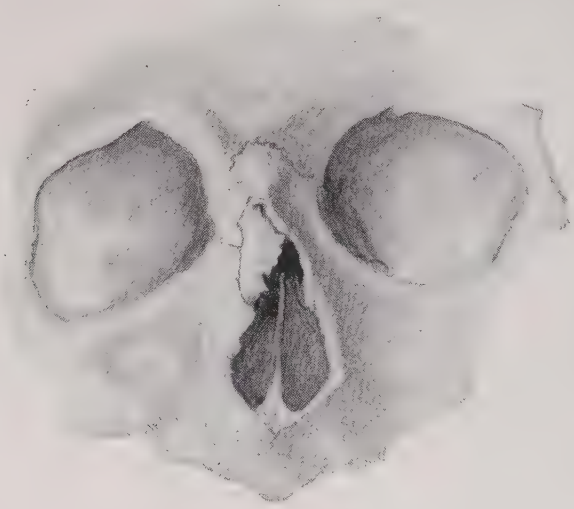


Fig. 503.—Fracture of nose with deflection of nasal bones laterally. (Davis: Applied Anatomy.)

obstruction, the former becoming more conspicuous with the subsidence of swelling. As union takes place rapidly, reduction should be attempted as soon as possible, and the chances of a successful result vary in direct ratio to the time elapsed since injury.

General anæsthesia or adequate local anæsthesia by adrenalin and novocaine are necessary in effecting reduction. By means of external manipulation and the aid of a narrow steel rod, protected by rubber tubing, passed upward beneath the nasal bones the depressed fragments may be elevated and the bones levered back into their normal anatomical position. Displacement of the septum may be corrected in the same manner, or it may be necessary to grasp the septum between the protected blades of a strong forceps and by appropriate manipulation to remodel it. After reposition of the fragments, there is usually little tendency to redisplacement, and external splints are of little use. When there is much comminution, and the bridge of the nose tends to fall in because of frac-

ture of the septum, intranasal splints of rubber tubing smeared with vaseline constitute a useful method of retention. Irrigation of the nasal cavities is generally to be avoided, because of the risk of carrying infection into the accessory nasal sinuses. It may be replaced by daily cleansing of the nares with cotton and the use of oleum petrolatum to soften crusts. Firm union is usually obtained in two to three weeks.

II. FRACTURE OF THE MALAR BONE AND ZYGOMATIC ARCH

Anatomy.—The malar bone and the zygomatic process of the temporal bone form the zygomatic arch; that is, the prominence of the cheek. This bony arch is palpable

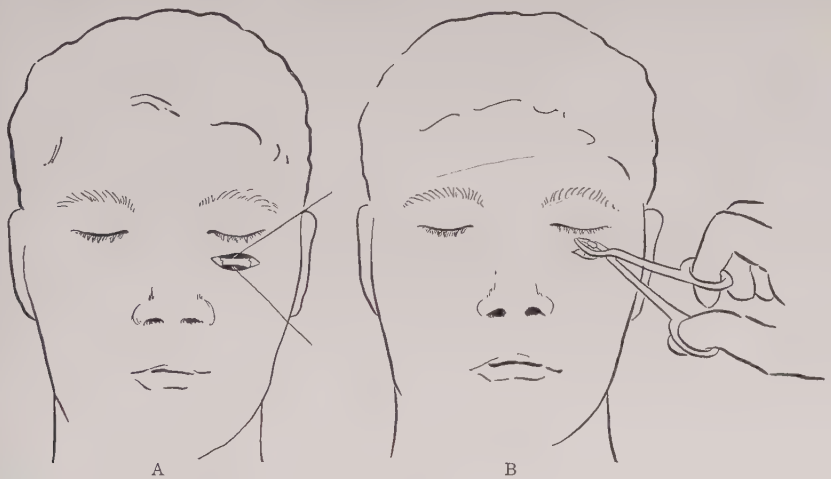


FIG. 504 (A, B).—Fracture of the malar bone; methods of open reduction. (A) Through a small incision, a wire may be passed under the depressed fragment which, by means of traction, is then elevated into position. (B) A small screw may be inserted in the bone and used as a means of traction.

throughout its extent from the tragus to the external angular process of the frontal bone, with which the frontal process of the malar bone articulates. The malar bone is quadrangular in shape and forms the outer border of the orbit and most of the wall which separates it from the temporal fossa. It articulates by means of its frontal, maxillary, and zygomatic processes with the frontal, superior maxilla, and temporal bones. The temporal fascia is attached to the upper border of the zygomatic arch, while from its lower border the masseter muscle takes origin. By pressing in deeply in front of the masseter muscle, the coronoid process of the mandible may be felt when the mouth is opened, and this is facilitated by bimanual examination with a finger inside the mouth.

Type of Fracture and Displacement.—Fractures of the malar bone may involve the body or its processes, and, if the violence falls further back, the zygomatic process of the temporal bone is fractured. The fracture is produced by direct violence, generally a blow on the outside of the bone, with resulting inward displacement of the fragments. In very severe injuries, the malar bone may suffer fracture-dislocation into the orbit or the maxillary antrum, but the question of importance then is

that of a fracture of the base of the skull. Fracture of the malar bone is not infrequently associated with a fracture of the maxilla, in which case the maxillary antrum is necessarily implicated.

Diagnosis.— The ordinary signs of fracture are usually present, the most characteristic feature, however, being the deformity from inward displacement or depression of the fragments, which is readily recognized on palpation of the zygomatic arch. When the displacement is marked, the action of the mandible may be interfered with by obstruction of the coronoid process. Subconjunctival hæmorrhage and bleeding from the nose are occasionally present.

Treatment.—An attempt should be made to reduce the displacement by outward pressure from within the mouth, combined with external manipulation. When these measures fail, it is necessary to elevate the depressed fragments by passing a suitable instrument beneath the bone either through an incision in the cheek just above the arch or from within the mouth through an opening in the mucous membrane along the line of its reflection from cheek to gum. In the case of fracture of the zygomatic arch, traction exerted on the ends of a loop of wire passed beneath it through a small incision furnishes a suitable means of raising the fragments. When the fragments in a fracture of the body of the malar bone are depressed into the maxillary antrum, it may be necessary to open the latter in order to elevate them into their normal position.

III. FRACTURES OF THE SUPERIOR MAXILLA

Anatomy.—The maxillæ are the largest bones of the face with the exception of the mandible, and compose the whole of the upper jaw. Each maxilla enters into the formation of the floor of the orbit, the floor and outer wall of the nasal fossa, and the roof of the mouth. The body of the bone is cubical and contains within it the cavity of the antrum of Highmore, a pyramidal-shaped chamber, whose apex is directed toward the malar process, and whose base forms the lateral wall of the nasal cavity. In fact, the maxilla develops around the antrum, which originates as an outward budding from the nasal mucous membrane. The walls of the cavity are very thin and follow in the main the orbital, nasal and zygomatic surfaces of the body of the bone. The internal surface of the antrum is lined by a muco-periosteum, which is continuous with that of the nose through an opening situated in the upper part of the inner wall which connects with the middle meatus.

The maxilla presents four processes; namely, the malar, nasal, alveolar, and palatal, which, together with the surfaces of the body and incidentally, therefore, the walls of the maxillary antrum, lie open more or less to external examination. This feature is appreciated in connection with tumors of the antrum, which, by causing progressive expansion of the body of the bone, distort the orbit, the nasal fossa, the mouth, and the infratemporal fossa. Normally, the edges of the upper incisor teeth lie a little further forward than those of the mandible, when the mouth is closed.

Types of Fracture.—Fractures of the maxilla may involve the body of the bone or its processes. They may take the form of very gross injuries with driving in of the body of the bone and partial or complete craniofacial disjunction, often involving the base of the skull, partial frac-

ture of the body with little displacement and deformity, or fracture of the alveolar, palatal, nasal, or malar processes. It has already been pointed out that fractures of the nasal, lachrymal, and malar bones may accompany these injuries. Bony displacement may cause serious distortion of the orbital, nasal, or oral cavities. The injury is frequently rendered compound by laceration of the skin of the cheek, or tearing of the mucous membrane of the mouth or antrum, and occasionally suppuration in the maxillary antrum develops as a complication.

Production.—The causative violence is usually direct, from a severe blow, a fall, or a kick from a horse, and the type of fracture resulting depends upon the severity and direction of the force. If the blow operates antero-posteriorly, the fracture usually takes the form of a gross backward displacement of the alveolar and palatal processes. If it strikes the jaw obliquely from above downward, the alveolar process is apt to be broken off in whole or in part. Fracture of the facial portion may be complicated by hæmorrhage from the infraorbital vessels and implication of the infraorbital nerve. In fracture of the nasal process, the lachrymal sac and nasal duct may be damaged and the flow of tears obstructed.

Diagnosis.— The diagnosis is usually not difficult because of the superficial situation of the bone and the conspicuous evidence of trauma. In the more severe injuries all the classical signs of fracture are present—swelling, ecchymosis, crepitus, deformity, and abnormal mobility. Surgical emphysema points to involvement of the antrum of Highmore.

The examination should include a careful inspection of the cavities of the nose and mouth and of the alignment of the teeth.

Treatment.— The displaced bones should be restored to their normal anatomical position whenever possible, not only in order to obtain a satisfactory cosmetic result, but also to prevent interference with the functions of the eye, the nose, and the mouth. Orbital distortion should be corrected, nasal obstruction cleared, and the normal alignment of the teeth restored. To accomplish this, operative reduction in one form or another is usually indicated. The depressed fragments may be elevated through a direct incision, preferably situated in the mucous membrane at its reflection from the cheek to the alveolar process, or it may be necessary to enter the antrum and lever them into position from within. Frequently it is difficult to maintain the reduction, but external splinting is of little value. When the alveolar portion is fractured, retention may be obtained by wiring the teeth, as in fracture of the mandible, or some form of interdental splint may be indicated. Union is usually quite solid in two to four weeks.

In the severe compound injuries, it is necessary to open up and cleanse the tissues as thoroughly as possible. Loose teeth and partially attached fragments of bone should not be removed, as they usually become firmly fixed again. Deformity should be corrected and the soft parts drawn

loosely together over bony defects, leaving ample room for drainage. It is wiser to defer the insertion of bone grafts and the performance of plastic procedures to a later period. The oral and nasal cavities should be kept clean by the use of mild antiseptic lotions. Gunshot wounds of the face and upper jaw with accompanying loss of bony substance and large defects in the maxilla and the soft tissues of the cheek, nose, and mouth constituted one of the most difficult of the surgical problems created by the war. Many of these were border-line cases falling between the realms of dentistry and surgery, and the outstanding feature of the treatment was the teamwork developed between dentist and surgeon, neither of whom alone was able to surmount the difficulties, but when working together were often able to achieve brilliant results in apparently hopeless cases. This lesson may frequently be applied with benefit when dealing with the ordinary traumatic cases.

IV. INJURIES OF THE MANDIBLE

1. DISLOCATION OF THE MANDIBLE

2. FRACTURES OF THE MANDIBLE

ANATOMY

The Body of the Mandible.—The mandible consists of a body and two rami. The body is horseshoe-shaped and is formed by the fusion of two symmetrical halves. The point of junction is at the symphysis and is marked by a slight indentation bordered on either side by the mental processes which form the prominence of the chin. The anterior surface of the body is marked by the external oblique lines, which run upward and backward on either side from the mental tubercles to become continuous with the anterior borders of the rami, and which separate the alveolar, or tooth-bearing, portion of the bone from the strong inferior border. The alveolar process is composed of thin bone, which surrounds the tooth sockets and is rapidly absorbed when the teeth are lost. The inferior border, or basal portion, on the other hand, is composed of very dense, tough bone, which at the symphysis is almost solid and is one of the last bones to show senile decay. The mental foramina are situated on either side just below the interval between the bicuspid teeth and transmit the mental vessels and nerve. The internal surface of the body is smooth and is marked on either side of the symphysis by two pairs of spines, the superior and inferior genial tubercles, which represent the points of insertion of the genio-glossal and genio-hyoid muscles, respectively. The internal oblique line extends upward and backward from the genial tubercles to the anterior border of the ramus and gives attachment to the mylohyoid muscles which form the muscular partition separating the oral cavity from the superficial region under the chin.

The Ramus.—The rami are flat plates of bone which join the posterior ends of the body of the mandible at an angle, the size of which varies according to the age of the patient, being nearly flat at birth, approaching a right angle in the adult, and again flattening in old age. The junction of the posterior border of the ramus with the inferior border of the body forms an important landmark, the angle. The upper portion of the ramus widens and terminates in two processes, the posterior one being the head or condyle of the bone, surmounted by an articular surface, while below is a constricted portion, the neck. The anterior or coronoid process is the higher of the two and furnishes the point of attachment for the temporal muscle. The hollow separating the two processes constitutes the sigmoid notch. The inferior dental foramen, the beginning of the dental canal which conveys the inferior dental nerve and vessels, is located in the inner surface of the ramus at about its centre. The masseter muscle has an extensive attachment to the outer side of the ramus, while the internal pterygoid

muscle is attached to the inner surface just above the angle and the external pterygoid to the condyle.

Ossification.—Each half of the inferior maxilla is formed from six centres, which become ossified during the first year. The two halves fuse at the symphysis during the first or second year.

Temporo-mandibular Articulation.—The temporo-mandibular joint is formed by the articulation of the condyle of the jaw with the glenoid fossa and eminentia articularis of the temporal bone. The capsule of the joint is loose to allow of free motion and is attached to the edges of the articular areas. The joint is divided into upper and lower compartments by the articular meniscus (discus articularis), which is interposed between the condyle and the glenoid fossa and held in position by capsular attachments. Into it the external pterygoid muscle is in part inserted. The external lateral ligament is an important structure and provides reinforcement to the capsule. Its

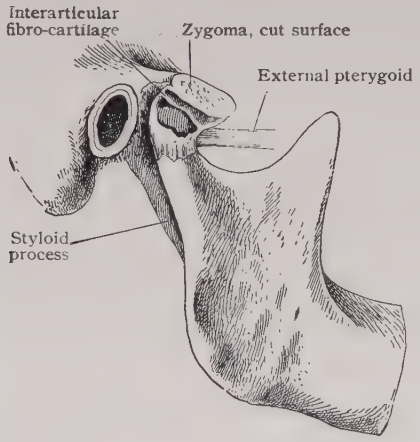


FIG. 505.—The temporo-mandibular articulation; the joint opened. (Piersol: Human Anatomy.)

fibres are directed downward and backward to the neck of the condyle and prevent forcible backward displacement of the mandible. The internal lateral, or spheno-mandibular ligament is not a true articular ligament and does not afford much additional security to the joint.

Movements of the Jaw.—The movements which take place at the temporo-mandibular joints are extensive. Thus the mandible may be depressed or elevated or carried forward and backward. There are two distinct joints in the articulation, each of which is concerned with a different type of motion. Thus the action of opening the mouth is accomplished by movement of a hinge-like character in the lower compartment between the condyle and articular disc, the condyle rotating on a transverse axis, while simultaneously in the upper compartment there is movement of a gliding character, the articular disc and condyle gliding forward on to the eminentia articularis. In protruding the mandible, the movement takes place mainly in the upper compartment and is of a gliding nature.

The mandible is depressed by its own weight, and by the action of the platysma, digastric, mylohyoid, and geniohyoid muscles. It is elevated by the temporal, masseter, and internal pterygoid muscles. It is protruded by the external pterygoid muscle and drawn backward by the deep fibres of the masseter and posterior fibres of the temporal muscles.

Surface Anatomy.—The greater part of the mandible is accessible to examination either externally or from within the mouth. The condyle may be palpated just below the zygoma in front of the ear and its movements followed when the mouth is opened and closed. The coronoid process is best felt, bimanually, with one finger inside the mouth, being situated just below the malar bone; the anterior border of the ramus may also be traced downward to its junction with the body. The internal surface of

the ramus is covered by the internal pterygoid muscle and the tense fibrous band of the pterygomandibular ligament can be felt mesial to it. The outer surface of the ramus is covered by the masseter, but its posterior border may be palpated, and at the level of the lobule of the ear, one finger's breadth below the zygomatic arch, the facial nerve can be rolled against the neck of the mandible.

I. DISLOCATION OF THE MANDIBLE

Mechanism.—Dislocation at the temporo-mandibular joint occurs practically only in the forward direction, but may be unilateral or bilateral. The latter is more common and occurs with particular frequency in women of middle age. It may be produced by direct violence, such as a blow directed downward on the chin when the mouth is open, but the most common mechanism is by muscular action from the sudden uncontrolled contraction of the external pterygoid muscles when the mouth is opened widely, as in the act of yawning or vomiting. When the mouth is widely opened, the condyles leave the glenoid fossa and come to lie on the extreme crest of the eminentia articularis, a situation which is relatively unstable and which may be readily converted into a luxation by a forward pull on the condyles by the external pterygoid muscle. The anterior and posterior capsular ligaments usually rupture, the condyles slip forward into the zygomatic fossa, the meniscus remaining behind, and the position of luxation is maintained by the contraction of the masseter, temporal, and internal and external pterygoid muscles.

Unilateral dislocation sometimes results from the unskillful introduction of a mouth-gag during anæsthesia or the taking of too big a bite. A condition of "subluxation" is described from relaxation of the ligaments, and this may go on to chronic recurrent dislocation from comparatively slight causes.

Diagnosis.— The diagnosis in the case of bilateral dislocation is usually fairly obvious from the appearance of the patient. The mouth is open, the jaw rigid, and the lower teeth project beyond the upper. The acts of swallowing and speaking are interfered with, and saliva dribbles from the mouth. The condyle of the mandible is palpable in its new position as a distinct projection, and a deep hollow may be felt behind it. The coronoid process lies in a distinctly lower position than normal, which may be recognized on bimanual examination, and the contracted temporal muscle stands out prominently above the zygoma.

In the case of unilateral dislocation, the clinical features are similar in character, but less obvious, so that in mild cases the dislocation may be overlooked. The chin is deviated away from the side of the dislocation as a rule.

Treatment.—The patient is seated on a low chair and an assistant supports the head from behind. The surgeon stands in front and places his thumbs, which are well protected by a roll of lint, far back on the molar

teeth and grasps the body of the jaw with his other fingers. By pressing downward and backward with the thumbs, the effort is now made to free the condyles from the eminentia articularis and to overcome the tension of the temporal and masseter muscles. The tip of the chin is then carried upward and the whole jaw pushed directly backward. The reduction often takes place with a snap. Sometimes extra leverage is necessary and may be obtained by placing a piece of cork between the molar teeth on each side, thus providing a fulcrum when the jaw is closed.

When reduction has been effected, the jaw should be fixed for a week

506

507

FIGS. 506 and 507.—Dislocation of the mandible. Method of grasping the mandible to obtain reduction.

or ten days by a four-tailed bandage, and care must be taken for some weeks not to open the mouth widely.

In old-standing dislocations attempts at reduction by manipulation repeated at intervals of two or three days if necessary may succeed in effecting reduction, but after a period of three months recourse must usually be had to operation. This takes the form of freeing the condyles from adhesions, at the same time detaching the mandibular attachments of the masseter and internal pterygoid muscles, which become shortened in the vertical position and offer an obstacle to reduction. Occasionally, it may be necessary to excise the condyle, and this procedure is usually followed by a very satisfactory result, provided that enough of the bone is removed to prevent interference with movement.

2. FRACTURES OF THE MANDIBLE

Causation.— Fracture of the mandible is almost always due to direct violence from the blow of a fist, a severe fall, or the kick of a horse. Fracture of the alveolar portion may result from faulty extraction of the

teeth. Occasionally examples of injury by indirect violence are encountered, such as fracture of the symphysis from lateral compression of the jaw, or fracture of the neck of the condyle from a blow on the chin. The fracture may be single or double and bilateral. The bone is rarely comminuted, but on account of the almost inevitable tearing of the covering mucous membrane, injuries of the body of the bone are usually compound.

Fracture of the Body.—The most frequent site of fracture is through the body in the region of the mental foramen where the bone is weakened not only by the presence of the foramen, but also by the large socket for

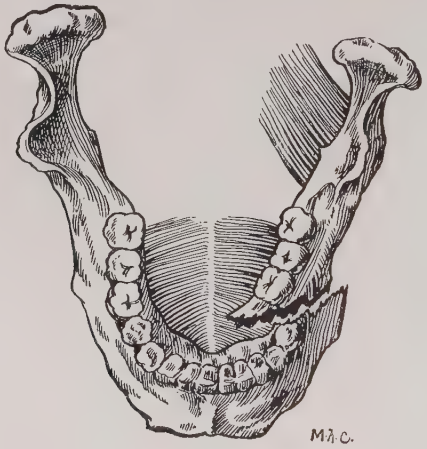


FIG. 508.—Fracture of the mandible, illustrating the action of the masseter and temporal muscles in displacing the posterior fragment.

the canine tooth. This is the classical fracture of the jaw, the fracture line being usually oblique, but its direction varying depending upon the character of the force and its mode of application. The presence or absence of displacement depends upon the direction of the fracture-line and the pull of the muscles attached to the fragments. When the fracture line passes downward and forward from the alveolar margin, little or no displacement may be found, as the pull of the depressor muscles attached to the chin and of the elevator muscles attached to the ramus and posterior portion of the body tend to approximate the fragments. When the line of fracture is oblique from above downward and backward, however, the geniohyoid, genioglossal, digastric, platysma, and mylohyoid muscles tend to depress the anterior fragment, while the posterior fragment is elevated by the masseter and temporal muscles and tilted forward and outward. When the fracture of the body is bilateral at the level indicated, the anterior, or middle fragment is pulled downward toward the hyoid bone and held there by the depressor muscles. A not uncommon bilateral type of fracture is one through the canine fossa on one side

and through the body of the mandible on the other side just in front of the attachment of the masseter muscle.

Fracture of the Symphysis.—Fracture through the symphysis is a rare injury because in the adult this is the strongest part of the body of the bone. Separation of the symphysis may occur in infants as a result of a

FIG. 509.—Fracture of the mandible by direct violence. Note the displacement of the tooth. (Fracture Service, M. G. H.)

glancing blow on the chin. In such cases the fragments are apt to be driven past each other by the action of the violence and are then retained in that position by the pull of the mylohyoid muscles.

Fracture of the Ramus.—Fracture through the angle, ramus, and coronoid are all more or less uncommon, and displacement is prevented by the splinting action of the masseter, internal pterygoid, and temporal muscles, which usually retain an attachment to both fragments.

Fracture of the Condyloid Process.— Fracture through the condyloid process, when it occurs, is apt to take place at the level of the neck. This is a serious injury because the smaller fragment retains its attachment

to the external pterygoid muscle, and in consequence is tilted forward and inward, a displacement which is beyond the reach of the ordinary methods of reduction. The chin and the remainder of the jaw are pulled toward the injured side by the internal pterygoid muscle of the opposite side. When the violence, usually a blow on the chin, is exceptionally

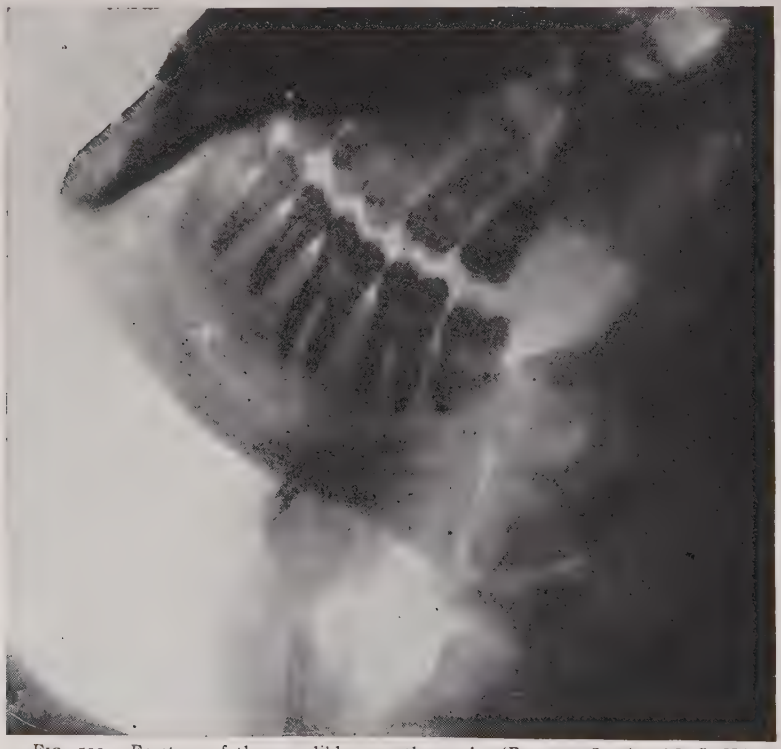


FIG. 510.—Fracture of the mandible near the angle. (Fracture Service, M. G. H.)

severe, the glenoid cavity may be fractured, and the injury may thus involve the base of the skull. Excessive callus formation is apt to result when the deformity is not corrected, and this may go on to actual ankylosis.

Diagnosis.— In the absence of displacement there may be present only swelling, pain and inability to move the jaw with freedom, but in fracture with displacement, abnormal mobility and crepitus are easily detected, and the bony deformity is evidenced by the deviation in the alignment of the teeth and the tearing of the mucous membrane at the point of injury. Fracture of the body is attended by great pain from involvement of the inferior dental nerve, which may be bruised, lacerated, or compressed by blood clot. The pain is increased by attempts to talk and to swallow, and the saliva, of which there is an excess, dribbles from the mouth and may be blood-stained. In fracture of the condyloid

process there is local tenderness and pain on motion. The displaced condyle may be palpated by a finger in the mouth and does not follow the movement of the jaw. The roentgenograms provide exact information and will clear up the diagnosis in doubtful cases.

Complications.—The teeth in the vicinity of the fracture are liable to be loosened or displaced, and a displaced tooth, by falling between the fragments, may result in non-union of the fracture. Teeth which are merely loosened and not displaced should not be removed, as they become firmly fixed again in a very short time. Dislocation may accompany the fracture and sometimes a fracture of the base of the skull. Union is usually solid in four to six weeks, and non-union is not common save in the case of gunshot wounds with loss of bony substance. Such cases generally require the operation of bone grafting for their cure. Malunion is more common and may result in disfigurement and interference with mastication from faulty alignment of the teeth. As the majority of fractures of the jaw are compound, suppuration is not unusual, but actual necrosis of the fragments does not often take place if careful attention is given to the cleansing of the mouth. Lesions of the inferior dental nerve usually clear up spontaneously.

Treatment.—The indications for treatment are to reduce the displacement so that normal alignment of the teeth is restored and the proper relationship between those of the upper and lower jaw (the "bite") is re-established, and by the use of proper retentive apparatus to secure immobilization of the fragments until healing of the fracture has occurred.

Reduction.—Reduction of the displacement may, as a rule, be readily accomplished by bimanual manipulation under general anæsthesia, at least in the early stages of the injury. In difficult cases it may be necessary to pry the fragments into line by the insertion of an appropriate instrument in the cleft between the alveolar portions of the two fragments, but this procedure considerably increases the risk of infection and should be avoided when possible. As has been previously stated, loosened teeth are not to be removed unless they actually interfere with reduction.

Fixation.—The methods employed to maintain reduction are many, and the choice of the procedure depends upon the facilities available as well as the indications of the particular case. In the simpler cases with little or no tendency to displacement, the fragments may be kept in position by the use of a four-tail, or Barton, jaw bandage. However, external fixation, even when secured by the use of special splints of plaster of Paris, gutta-percha, or poroplastic, is of little value when dealing with cases of displacement. Intraoral methods of fixation must then be used. The underlying principal in practically all such procedures is the use of the upper jaw as a coaptation splint, to which the lower jaw is fixed, correct position being assured by the approximation of the upper and lower

sets of teeth. This presupposes that the teeth are present in sufficient number to provide a means of fixation or retention. In cases of fracture when the teeth are lacking, external fixation combined with some form of interdental splint is required.

In the class of case, then, where there is displacement and difficulty in maintaining reduction, intraoral fixation by means of interdental splints or by wiring of the teeth should be employed. A great number of procedures have been devised for securing intraoral fixation, but in the major-

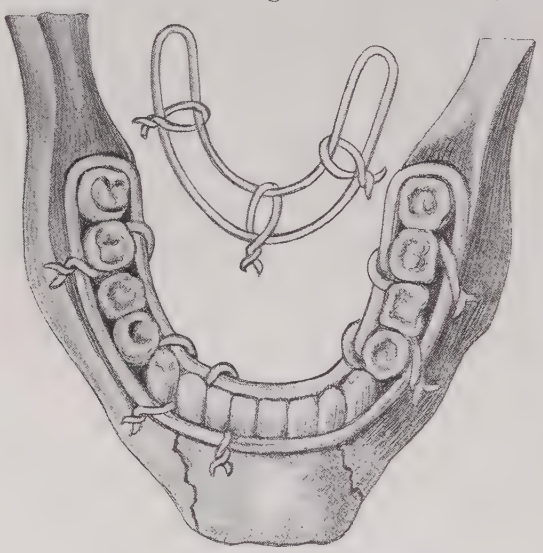


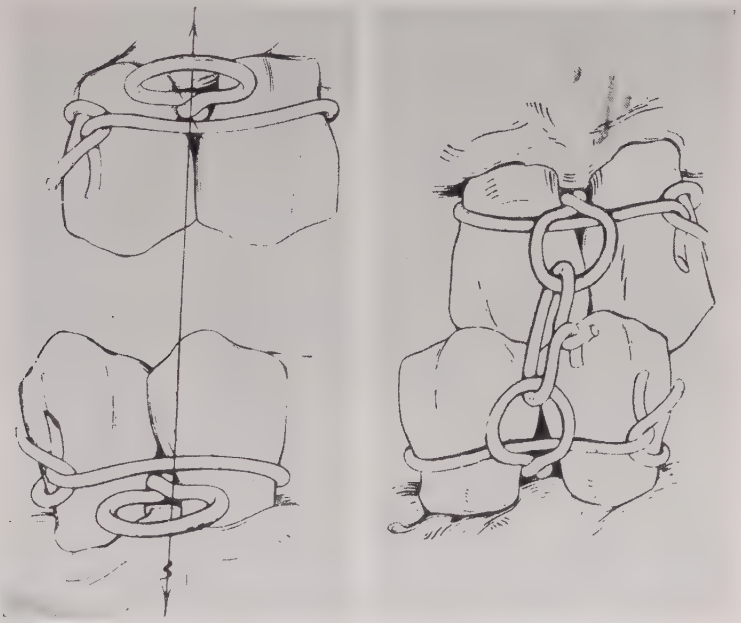
FIG. 511.—Interdental splint applied.

ity of these the apparatus required is so elaborate and intricate that a considerable time is necessary for its fabrication, and only a dental surgeon with special training and a well-equipped workshop can undertake its manufacture and adjustment. Many of these methods are intended to meet only rare and unusual conditions and in the ordinary case have no real advantage in spite of their greater mechanical perfection over far simpler procedures.

Interdental Splint.—When an interdental splint is required, particularly in difficult bilateral fractures, Hammond's apparatus is satisfactory (Fig. 511). An impression is taken of the deformed jaw from which a plaster model is made. The latter is then sectioned at the point of fracture and the two portions fastened together in a position of correct alignment. A light silver frame is then prepared from this model, being accurately moulded so as to conform to the contour of several teeth on each side of the fracture. The frame is then applied to the patient's jaw, the individual teeth being surrounded by loops of wire and fastened firmly to the splint, and in this way solid fixation in correct alignment is obtained. This

apparatus is within the capabilities of the average dental surgeon, but is not immediately available.

Intraoral Fixation with Wire.—Because of this fact, and also on account of the need for a method which can be easily acquired by the general surgeon and practitioner, Ivy [1] has described a method of wiring the teeth which may be depended upon to do all that is necessary in the ordinary case or to provide adequate fixation while an interdental splint is being made (Figs. 512 to 516). The wire is of such a size that it will pass freely



512 513

FIGS. 512 and 513.—Method of wiring the teeth in fracture of the jaw. See text. (Ivy, Surgery, Gynecology, and Obstetrics.)

through the spaces at the neck of the teeth; No. 22 gauge copper wire and Nos. 24-26 gauge Angle's brass ligatures wire are used, and the instruments required are a pair of artery forceps, a pair of short-nosed scissors and a tenaculum, or towel clamp. A 6-inch length of wire is twisted in the form of an eyelet around the towel clamp. Both ends of the eyelet wire are inserted from the buccal surface through the space between the necks of the teeth selected and the ends twisted around the anterior and posterior surfaces of the tooth back to the buccal surface. The process is repeated on the corresponding upper teeth. Then the ends of the wire are twisted together in such a way that the eyelet projects below and above the twist in the lower and upper jaw respectively. While the tightening of the wire loop is being effected by twisting the ends with the forceps,

[1] R. H. Ivy, *Surg., Gyn. and Obstetrics,* 1922, Vol. 34, p. 670.

the eyelet must be prevented from dislodgment by engaging it with the towel clamp. The ends are then cut short and turned in. The process may be repeated in the opposite side of the mouth and even at a third place if necessary. The upper and lower eyelets are now connected by passing through them a connecting or tie wire of brass, and close approxi-

514

515

FIGS. 514 and 515.—Method of wiring the teeth. (514) Insertion of wire loop. (515) Wiring completed. (Ivy, Surgery, Gynecology and Obstetrics.)

mation is thus secured. If an anæsthetic is required, the placing of the tie wire is omitted until the danger of nausea is past, and the means should always be at hand to undo it quickly in case of emergency.

General Measures.—The strictest attention to the cleanliness of the mouth must be observed, as fractures of the body of the mandible are generally compound, and the fixation apparatus, by closing the jaws, predisposes to stomatitis. The mouth should, therefore, be rinsed

with a mild antiseptic or alkaline lotion several times a day, particularly after taking food. A liquid diet is necessary, and care must be taken to see that it is sufficiently adequate to maintain nutrition. Milk and cream are the staple articles, but to these may be added thick soups of sufficient variety to break the monotony and fruit juices and hot and cold drinks of various kinds.

Gunshot Injuries.—Compound fractures of the mandible resulting from gunshot wounds, such as seen in the late war, constitute a special problem apart from the ordinary fractures. Such cases are frequently

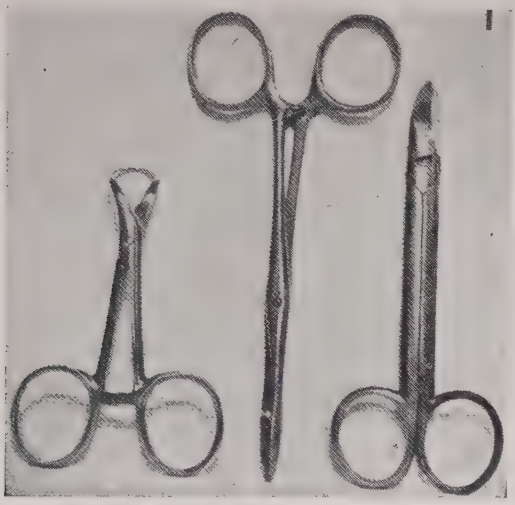


FIG. 516.—Instruments used in wiring teeth. (Ivy, Surgery, Gynecology and Obstetrics.)

complicated by extensive, soft part injuries, and loss of bony substance, creating a large defect to be filled. These extremely varied and difficult war cases gave a great impetus to oral surgery, and the value of modern dentistry was strikingly demonstrated by the skill with which these cases were handled. Deformity of the jaw must be prevented or corrected by the use of special splints or traction appliances, while the soft parts are healing. Proper sanitation of the mouth must be maintained. Later, the bony defect is closed by the insertion of a bone graft, and plastic operations to correct disfigurement are performed when necessary.

Open Reduction.—Open reduction of the fracture in the ordinary traumatic cases is unnecessary as a rule and contraindicated on account of the pre-existing compound nature of the injury. Fracture of the neck of the mandible with displacement which cannot be corrected by ordinary intraoral methods is an exception to this rule, and operative replacement of the bones may be necessary. Such injuries are rarely compound, so the risk of infection is slight.

CHAPTER XII

INJURIES OF THE THORAX

I. FRACTURE OF THE RIBS
II. FRACTURE OF THE COSTAL CARTILAGE
III. FRACTURE OF THE STERNUM
IV. INTRATHORACIC COMPLICATIONS
V. OPEN WOUNDS OF THE CHEST WALL

ANATOMY OF THE THORAX

The Ribs.—The thoracic wall is formed by twelve pairs of ribs, of which the upper seven are sternal, or true ribs, and the lower five, vertebral, or false ribs. A typical rib is made up of a head, neck and body. The head is the expanded posterior extremity of the bone, which articulates with the body of the vertebra, forming the costocentral articulation. The tubercle is a prominence lying near the head, but separated from it by a constricted portion, the neck, which articulates with the transverse process of the vertebra, forming the costotransverse joint. The body of the rib begins at the tubercle, and situated near it is the so-called angle, the point where the rib changes its direction. The ten upper pairs of ribs are joined to the sternum by means of costal cartilages, those of the upper seven being separate and direct, while those of the eighth, ninth and tenth fuse with the cartilage of the seventh rib, and their junction with the sternum is indirect. The first rib is short and flat and differs considerably from the other ribs. The eleventh and twelfth ribs are also peculiar, being short and less fully curved than the others, and because their anterior ends are not joined to the sternum, they are known as floating ribs.

The ribs ossify by three centres, one each for the shaft, head and tubercle. Those for the head and tubercle appear at the sixteenth year and unite at twenty-one.

Vessels and Nerves.—The intercostal spaces are occupied by the intercostal muscles and by the intercostal vessels and nerves. Posterior to the costal angles the latter cross the space obliquely to reach the costal groove placed at the lower border of the inner surface of the rib; the arrangement of these structures is vein, artery, nerve, from above downward. In aspirating the chest, therefore, the needle must be inserted at the upper border of the rib to avoid these structures. The internal mammary artery descends upon the costal pleura half an inch from the sternum and is related in front to the internal intercostal muscles and the costal cartilages. At the sixth interspace it divides into the superior epigastric and musculophrenic arteries. Ligation of the internal mammary artery is best done in the second intercostal space.

The Sternum.—The sternum consists of three portions, the manubrium, gladiolus, and ensiform cartilage. The anterior surface of the sternum is palpable throughout its entire extent. The junction of the manubrium with the gladiolus is marked by a transverse ridge at the level of the second costal cartilage, the sternal angle. This constitutes an important landmark in counting the ribs, as it marks the level of the second costal cartilage.

The Pleura.—Superiorly, the pleural cavity bulges into the root of the neck for a distance of about one inch, and is occupied by the apex of the lung. The line of the cervical pleura may be indicated on the surface by a curved line with an upward convexity drawn from the centre of the sterno-clavicular joint to the junction of the inner and middle thirds of the clavicle. Inferiorly, the pleura is reflected from the lower ribs on to the diaphragm at a point situated about two fingers' breadth below the lower border of the lung, and the costo-diaphragmatic line of pleural reflection may be indicated by a line drawn from the junction of the gladiolus and xiphoid process of the sternum

to the twelfth dorsal spine. The former point marks the lower end of the costo-mediastinal line of pleural reflection, and the line indicated crosses the eighth costochondral junction in the midclavicular line and the tenth rib in the midaxillary line. The space which exists between the lower border of the lung and the lower limit of the pleura in

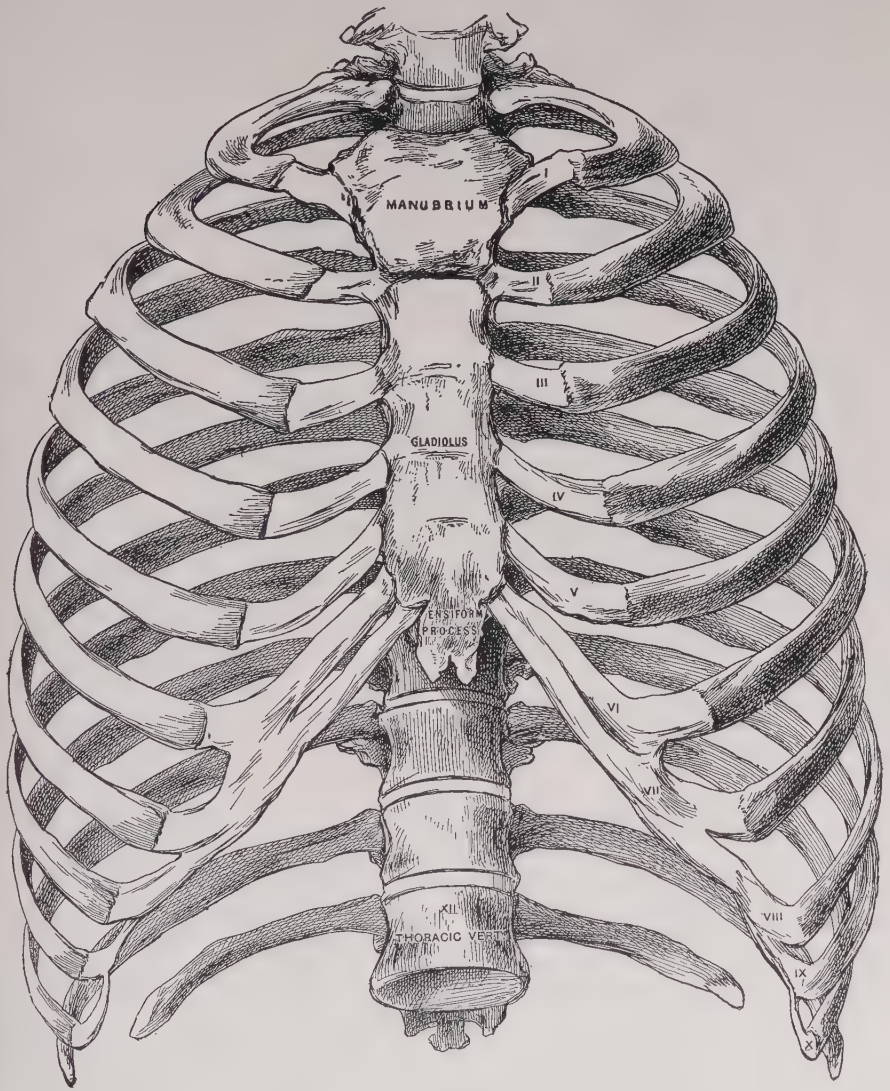
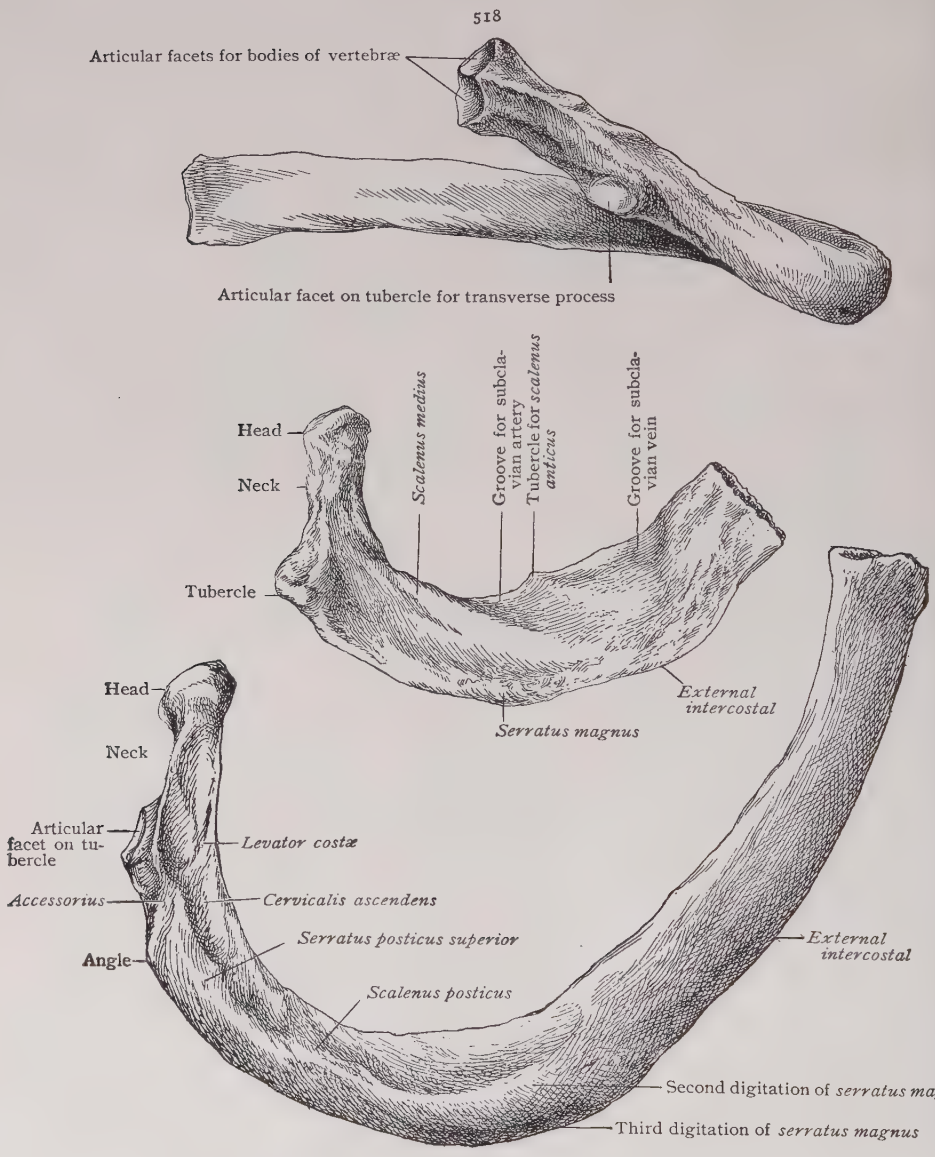


FIG. 517.—Bony thorax, anterior view. (Piersol: Human Anatomy.)

quiet respiration is known as the costophrenic sinus, and the costal and diaphragmatic pleura are here in contact. On the right side the costophrenic sinus is related to the liver and kidney, and on the left side, to the left lobe of the liver, the stomach, spleen, and left kidney, in that order, from above downward.

Behind the manubrium lie the left innominate vein and branches of the aorta. The arch of the aorta is situated behind the sternal angle.



Figs. 518 and 519.—(518) Right fifth rib from behind. (519) First and second ribs of right side; upper surface. (Piersol: Human Anatomy.)

I. FRACTURE OF THE RIBS

Direct Violence.—The ribs are rarely fractured in childhood because of their great elasticity; greenstick fractures, however, do occur. In adults subperiosteal fracture of a single rib may occasionally be produced

by severe muscular action alone, as from a cough or sneeze, and such a fracture may be somewhat difficult to detect. In the majority of cases, however, the ribs are fractured by direct violence, and the injury occurs at the point where the force is applied. The fragments may be driven

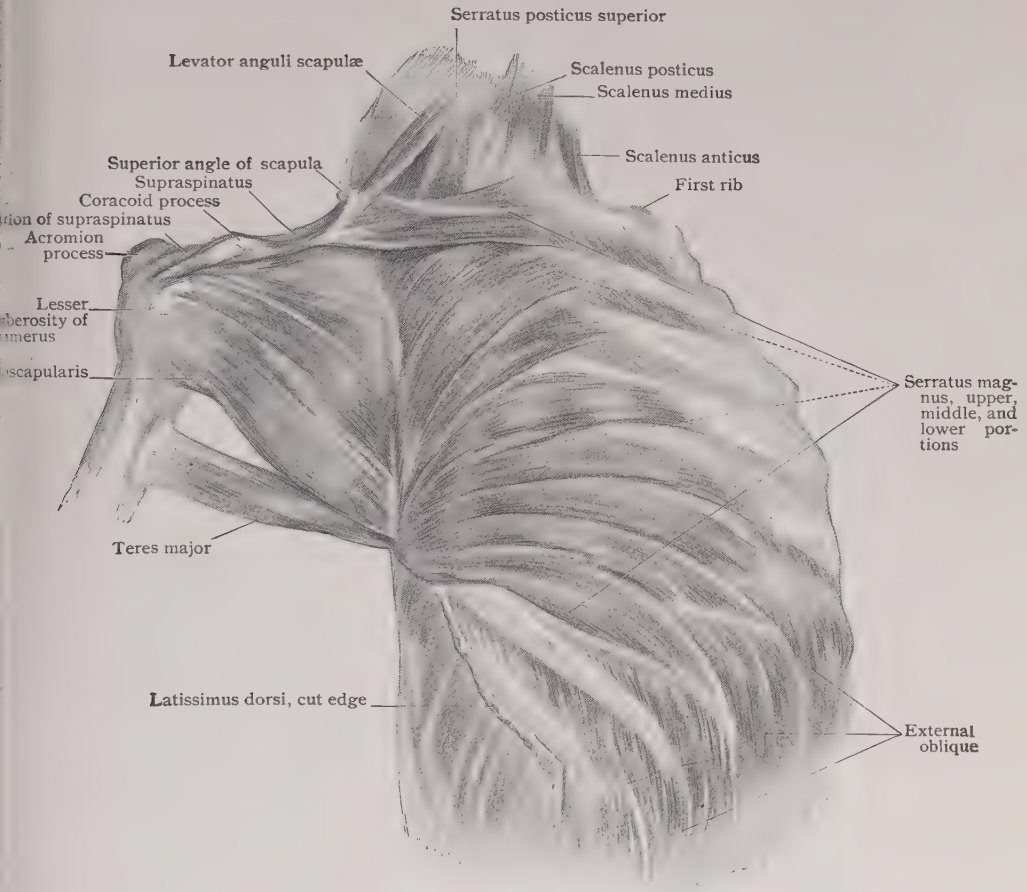


FIG. 520.—Dissection of thoracic wall showing serratus magnus; clavicle has been removed and scapula drawn outward. (Piersol: Human Anatomy.)

inward and injure the pleura or the lung. Gross displacement is not usual even when a number of ribs are broken, and union takes place rapidly and is usually solid in three to five weeks' time.

Indirect Violence.—When the injury is produced by indirect violence, several ribs are apt to be broken, and this injury constitutes a special type of fracture. The classical means of causation is by compression of the thorax from a crushing injury, and the ribs give way at the point of maximum convexity and weakness, usually just in front of the angles.

Any displacement tends to be outward, so that injury of the pleura and lung is less common than in fracture by direct violence.

The first and second ribs are protected by the clavicle and do not often suffer fracture; and the eleventh and twelfth ribs, by virtue of their shortness and mobility, also usually escape injury. The fourth to the eighth ribs are those most frequently fractured.

Diagnosis.— The diagnosis of fracture of the ribs is usually fairly obvious from the description of the trauma and the type of pain which

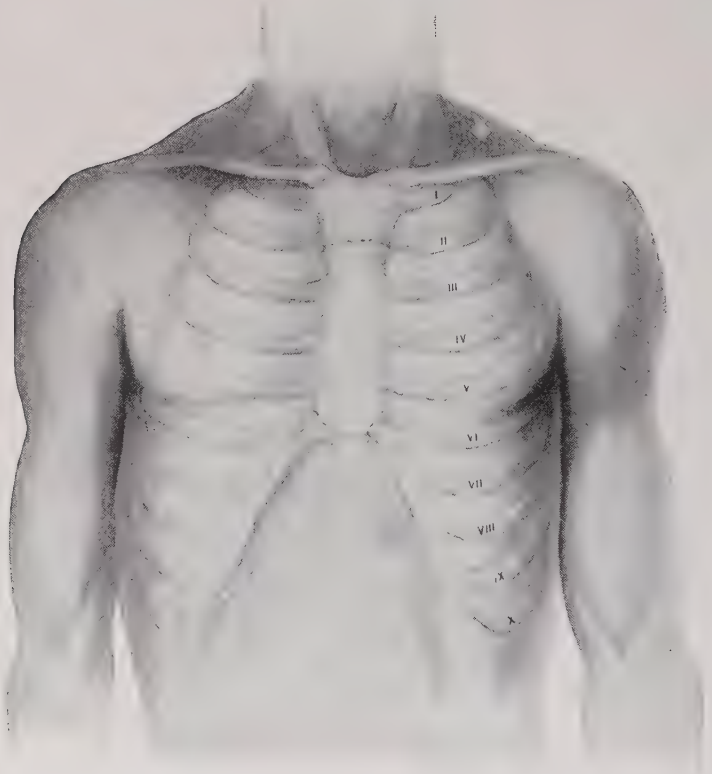


FIG. 521.—Anterior surface relations of the lungs and pleuræ. (Davis: Applied Anatomy.)

the patient suffers. The latter is very severe, and, because it is affected by respiratory movements, the character of the breathing is considerably altered, being shallow and catchy from the effort of the muscles to fix the affected side of the chest. For the same reason, the patient is usually more comfortable when sitting, rather than lying. The most constant findings on examination are local tenderness on pressure and pain referred to the seat of injury on antero-posterior compression of the chest. In the case of injury by direct violence, there may be local evidence of trauma, such as contusion of the skin and swelling. Ecchymosis rarely appears

before the end of several days. In the case of multiple fractures from direct violence, it may be possible to detect an actual depression of the chest wall. Crepitus may be felt in a considerable number of cases in the form of a sharp click on forced inspiration, and this may also be heard when the stethoscope is applied to the chest wall over the point of injury.

Complications.— The complications which are likely to ensue from fracture of the ribs are those arising from accompanying injury to the pleura

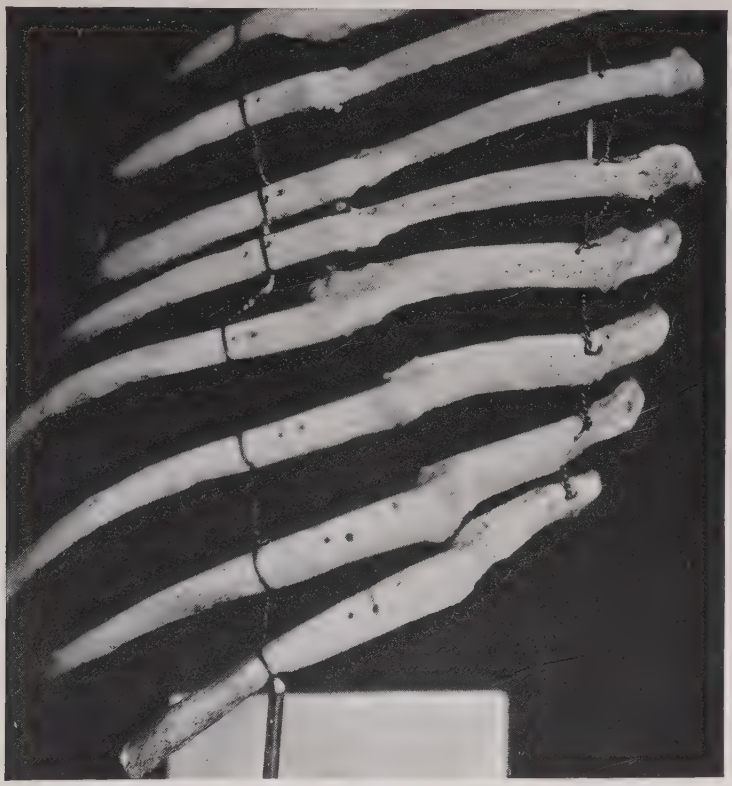


FIG. 522.—Multiple fracture of the ribs. (Specimen from Warren Anatomical Museum.)

and lung, and consist chiefly of hæmothorax, pneumothorax, hæmoptysis, and subcutaneous emphysema. These conditions are discussed elsewhere (see pp. 422-424), and it only remains to emphasize here that they may occur in cases of apparently simple injury and that the examination should be sufficiently thorough to demonstrate their presence or absence. Subcutaneous emphysema is frequently present and of itself is an indication of injury to the lung. It is readily recognized as a fine crackling sensation when the hand is pressed against the surface of the skin. Hæmothorax, and pneumothorax, particularly when the latter is associated with an

open wound of the chest wall—as from gunshot injury—far overshadow in importance the bony lesion itself and constitute the urgent indications for treatment.

Treatment.—In uncomplicated cases the aim of treatment is to relieve pain and secure immobilization of the affected side of the chest. The

FIG. 523.—Fracture of the seventh and eighth ribs.

rib fragments are rarely displaced sufficiently to cause any serious difficulty and except in cases of severe injury, with caving in of the chest wall so that the ends of the bones project inward and cause damage to the lung, replacement of the fragments or reduction of the deformity need not be attempted. Simple retentive measures to provide rest for the fracture until union has taken place are all that is necessary. In the severe cases, rest in bed with the shoulders elevated is at first essential.

Adhesive Plaster Strapping.— Satisfactory immobilization of the fracture may be obtained by fixation of the affected side of the chest with an adhesive plaster strapping. The strips of adhesive are of two inches' breadth and of sufficient length to reach a little more than half way around the chest. They are applied in an overlapping manner from below

FIG. 524.—Fracture of rib.

upward, the chest being in a position of expiration as each strip goes on. The ends of the strips should extend slightly beyond the midline on both the anterior and posterior surfaces of the chest. The skin should be shaved before the application of the plaster, and if the nipple is covered, this should be protected by a small square of gauze. In the case of a woman with a large breast this should be lifted upward as the strapping is applied. The upper and lower limits of the strapping should extend two to three

inches above and below the level of the affected ribs. A flannel bandage around the chest completes the dressing.

Later Treatment.— The strapping should be renewed each week until there is disappearance of symptoms. If the skin becomes irritated at any time, the strapping should be removed, the irritated portions of the skin

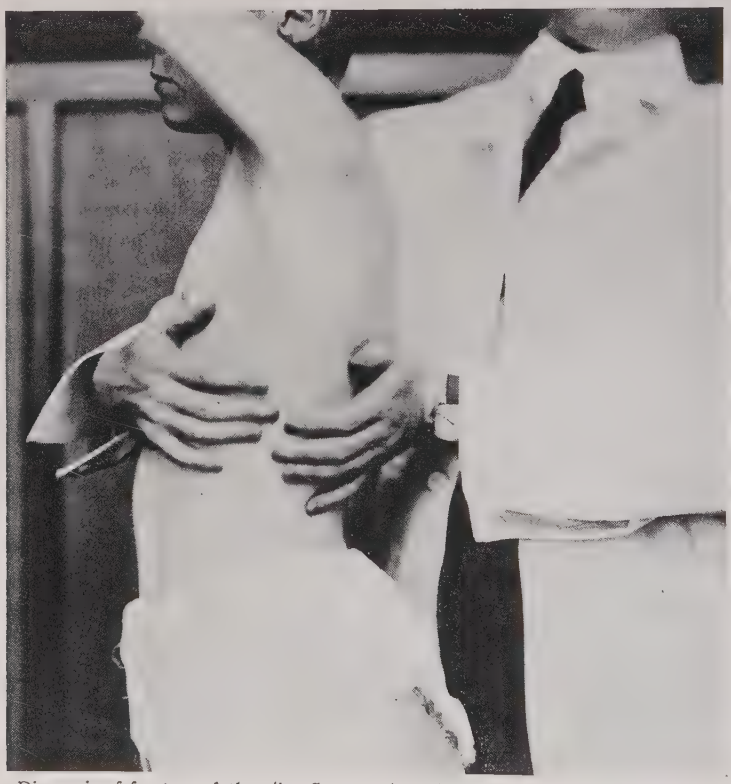


FIG. 525.—Diagnosis of fracture of the rib. Compression of the chest in the antero-posterior diameter elicits pain at the site of injury.

anointed with zinc oxide ointment and protected with small squares of gauze, and the strapping re-applied. In the later stages of the injury a flannel bandage or tightly-pinned swathe encircling the chest may be substituted for the strapping.

Fixation of the Shoulders.— When one of the upper four or five ribs is involved, considerable pain results from movements of the shoulders, due to the strain transmitted to the ribs by the fibres of the pectoral muscles. In such cases considerable relief may be obtained by the use of a figure-of-eight webbing strap, which passes around the front of the shoulders, the ends being crossed over the back and then brought around on either side in front, where they are secured either to each other or to the

clothing. By such means the shoulders are drawn backward and held so that the strain on the ribs is relieved.

General Measures.—General measures of treatment are important. The value of bed treatment in the early stages of injury has been already mentioned. In addition small doses of morphine should be given at frequent intervals to relieve pain. Very real difficulty is often encountered in the severe cases from abdominal distention, and this may cause mechanical interference with the action of the diaphragm and still further embarrass the shallow and painful respiration. When once established, the condition is difficult to relieve, and prevention by early attention to the bowels is the best method of treatment. Mild laxatives and enemata should, therefore, be employed from the beginning, and in case distention begins to develop, it should be immediately combated, by the use of saline laxatives, high enemata, and the insertion of a rectal tube. A liquid diet during the first few days is also indicated.

In cases of fracture with associated injury of the lung, the resistance of this organ to infection is considerably lowered, and broncho-pneumonia is a not infrequent complication and may terminate fatally. Because of this danger, when the fracture of the ribs is associated with other injuries, which require operative treatment, the use of general anæsthesia is to be avoided whenever possible, and when it is essential, nitrous oxide and oxygen are to be preferred to ether.

II. FRACTURE OF THE COSTAL CARTILAGES

The costal cartilages may occasionally be fractured as a result of direct violence. The injury usually takes place near the costochondral junctions, and the cartilages of the seventh and eighth ribs are the ones most frequently involved. The treatment is the same as in fracture of the ribs, though the method of firmly bandaging the chest with a flannel bandage put on over an undergarment, to which the turns are stitched, may prove a less irksome and equally satisfactory means of retention.

III. FRACTURE OF THE STERNUM

Causation.—Fracture of the sternum is a very infrequent form of injury, because of the protection afforded the bone by the mobility and elasticity of the thorax. The causative violence is usually direct in its action and in the nature of a severe blow. The sternum may also be broken by severe forms of indirect violence which cause excessive bending of the body in the direction of flexion, and fracture of the spine may be associated with the injury. In many of these accidents the ribs are also fractured and gross damage inflicted upon the intrathoracic viscera.

Type of Fracture.—The common site of fracture is at or just below the junction of the manubrium and body, and the line of fracture transverse, with or without displacement. When displacement occurs, it is almost constantly one where the upper end of the lower fragment overlaps and lies in front of the lower end of the upper fragment. In young children the injury may take the form of a dislocation between the gladiolus and manubrium.

Diagnosis.— The diagnosis is usually fairly obvious. Locally there is pain and tenderness and later ecchymosis at the seat of the fracture. Actual bony deformity may be palpable and a definite prominence felt. As the pain is increased by motion, the patient maintains the head in an attitude of flexion, and the respiration is shallow and rapid. There may be dyspnœa and expectoration of blood in the more severe cases. The treatment is by recumbency in the dorsal decubitus with a small, firm pillow between the shoulders, the aim being to prevent over-riding of the fragments. When overlapping does exist, reduction should be attempted by hyperextending the neck and upper portion of the body over a large, firm cushion, at the same time pressing directly upward and backward on the lower end of the upper fragment and drawing the arms upward and outward. Union in the deformed position, however, is followed by no serious after-results, a fact which should be remembered in case operative replacement of the fragments is considered. Solid union may be expected in about six weeks.

FIG. 526.—Fracture of sternum. (Warren Anatomical Museum.)

IV. INTRATHORACIC COMPLICATIONS OF INJURIES OF THE RIBS AND STERNUM

Injury of the pleura, or lung, may complicate any of the above injuries, and in such an event, the recognition and treatment of the complicating condition are of far greater importance than the treatment of the fracture itself. Because one is the result of the other, however, it usually follows that the measures instituted for the relief of the first are also of direct advantage to the other, but this is not necessarily so.

Hæmothorax.—Hæmorrhage from laceration of the lung is evidenced by the occurrence of hæmoptysis and hæmothorax of varying severity. The former is rarely serious and may be completely absent even with serious hæmorrhage into the pleural cavity. The symptoms are those of

hæmorrhage and shock associated with dyspnœa, and in the event of hæmothorax, these are combined with signs of a gradually increasing pleural effusion and displacement of the heart to the opposite side of the chest. Hæmorrhage from the internal mammary or intercostal arteries is of rare occurrence except in open wounds of the chest wall, resulting from gunshot injury.

Pneumothorax.—Injury of the visceral pleura and underlying pulmonary vesicles allows air to escape into the pleural cavity and produces the condition of pneumothorax. A small degree of pneumothorax produces no serious effects, the air being gradually absorbed, but in the severe cases, with each movement of respiration, more air is pumped into the pleural cavity, the lung is compressed, and serious symptoms from pressure result. There is severe dyspnœa accompanied by restlessness and cyanosis. The physical signs of pneumothorax include a bulging of the intercostal spaces, displacement of the heart, and a high-pitched, tympanitic percussion note.

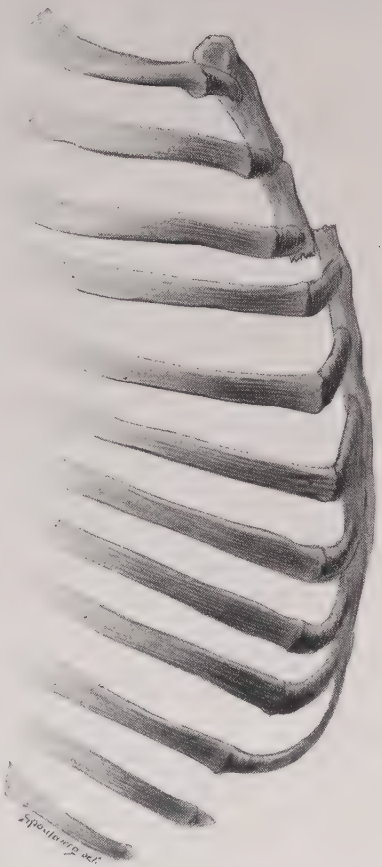


FIG. 527.—Fracture of sternum, showing overlapping type of displacement.

Subcutaneous Emphysema.—Surgical or subcutaneous emphysema is the most common condition indicating injury of the lung and pleura. It usually is produced by involvement of both the parietal and visceral walls of the pleural cavity. A localized pneumothorax develops, but does not cause serious symptoms, because at each expiration the air is expelled from the pleural cavity into the subcutaneous tissue. As a rule, it is of no serious significance and ceases when the pleural wounds become sealed over with exudate. The emphysema is at first localized in the vicinity of the injury, but later spreads to the neighboring regions. The affected area becomes swollen and puffy and gives a sensation of fine crackling when palpated; generally, the actual amount of discomfort is slight in comparison with the objective findings. When the pleura remains intact and the lung tissue is torn, an interstitial form of emphysema may develop, which is much more serious. The air escapes into the peribronchial connective tissue and thence into the mediastinum and root of the neck, and from there spreads to the rest of the body.

Treatment.—The treatment of these complications consists primarily in keeping the patient absolutely quiet in a warm room. In case of serious hæmorrhage, it is necessary to make up for the loss in blood volume by the subcutaneous, intravenous, or rectal administration of saline solution or the transfusion of blood. Hæmoptysis is treated by the administration of cracked ice and the use of opium in small and frequently repeated doses

FIG. 528.—Old healed fracture of sternum. (Army Medical Museum.)

to quiet the restlessness. Severe dyspnœa resulting from pleural effusion may be relieved by aspiration. A small hæmothorax which does not increase in amount generally takes care of itself, but a large hæmothorax requires aspiration. Not all the fluid should be withdrawn at once for fear of starting the bleeding afresh. The aspiration must usually be repeated once or twice, as the fluid reaccumulates to a certain extent. Operative opening of the thorax for the purpose of arresting hæmorrhage is usually unsuccessful in obtaining its chief objective, and by the time such a procedure is resorted to, the patient is generally in such desperate condition that he is unable to withstand the shock. Conservative procedures such as aspiration and repeated transfusion of blood are, therefore, apt to hold forth more hope of relief than radical treatment.

Pneumothorax, if causing serious respiratory difficulty, may also be relieved by aspiration of the air in the pleural space. Subcutaneous emphy-

sema rarely requires any treatment, but in case it is severe enough to cause circulatory and respiratory embarrassment, the method of making multiple superficial incisions in the regions most distended with air may be employed, and cases are on record where this has given relief.

V. OPEN WOUNDS OF THE CHEST WALL

Respiratory Effects.—Open wounds of the chest wall usually result from gunshot injuries, and the problems presented are: first, the effects of the opening in the chest wall on the mechanics of respiration; second, the extent of the damage done to the lung and neighboring structures; and third, the risk of subsequent infection. It has been shown that in the case of a small wound of the chest wall, the two layers of the pleura adhere by capillary attraction of the moist surfaces, and that such an injury is not necessarily followed by the collapse of the lung but, if the opening is valvular so that air is drawn in with each inspiration and cannot be expelled by expiration, serious compression of the lung may follow. If the opening in the chest wall is large, as occurred in the cases of war injury, the air rushes into the pleural cavity, and the lung collapses. The mediastinum is drawn over toward the healthy side, which is further embarrassed in consequence. Such cases are attended by severe shock.

Treatment.—The immediate treatment should be directed toward the combating of shock when this is present, and all the usual measures should be employed, including the application of heaters, the administration of morphine, and the intravenous or subcutaneous injection of saline solution, or blood transfusion. The wound should be dressed, and, if small and completely occluded, a dry gauze dressing is sufficient. If, on the other hand, air is entering the pleural cavity, a simple operation under local anæsthesia should be performed to pull the muscular and cutaneous coverings of the chest wall together and occlude the opening. If no serious damage has been caused to the lung or neighboring structures, the general condition rapidly improves and the problem of further treatment can then be considered.

In cases of recent injury it is necessary to decide whether conservative treatment should be followed, or débridement performed. Septic complications from gunshot wounds in peace time occur much less frequently than in the case of war injuries, and conservative treatment is, therefore, the better policy. The pleural cavity should be aspirated on the second or third day as routine, and earlier if indications arise, and cultures made from the fluid. In case the presence of pyogenic organisms is demonstrated, thoracotomy for the purpose of drainage, at the lowest pleural level, should be performed. Later, when sufficient time has elapsed for the infected portion of the cavity to become firmly walled off, chemical disinfection by the Carrel-Dakin method may be instituted.

CHAPTER XIII

INJURIES OF THE PELVIS

ANATOMY OF THE PELVIS

The pelvis is composed of the two innominate bones and the sacrum, which are united in front by the symphysis and posteriorly by the two sacro-iliac articulations. It is divided into two portions, the false and the true pelvis, by a plane passing from the top of the pubes to the promontory of the sacrum. The false pelvis is formed

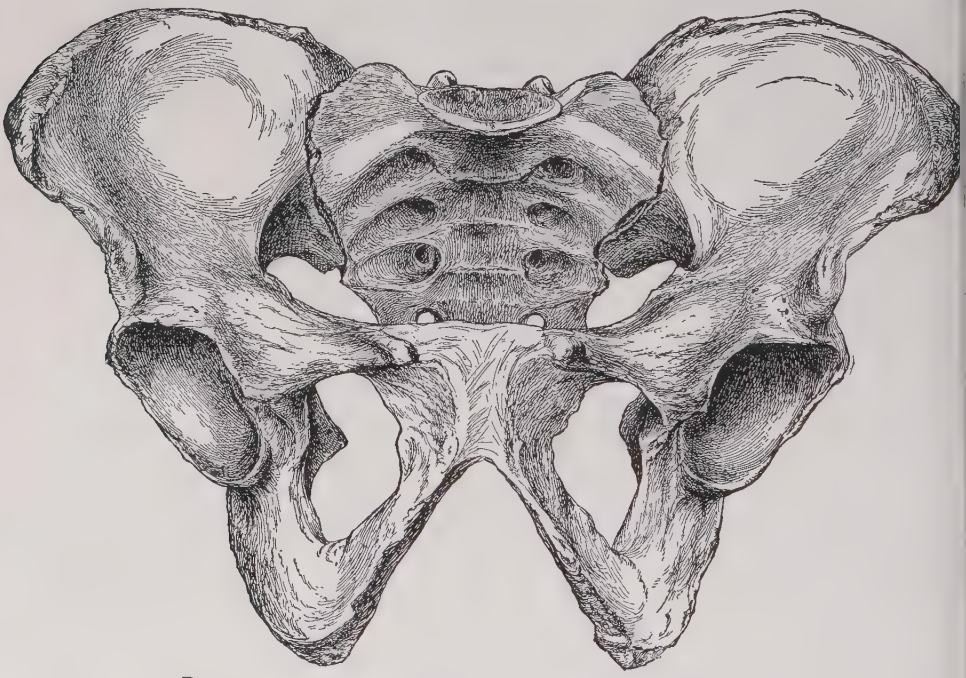


FIG. 529.—Pelvis viewed from the front. (Piersol: Human Anatomy.)

chiefly by the wings of the ilia, while all three bones enter into the formation of the true pelvis or pelvic ring. The dividing line is represented by a bony ridge and is known as the brim.

The Innominate Bone.—The innominate bone is composed of three separate osseous portions, the ilium, pubis and ischium, which fuse in early life. The pubis consists of a body which joins with its fellow of the opposite side to form the symphysis, and of the superior and inferior rami, which form the upper and mesial borders of the obturator foramen. The ilium is a large, flat bone which forms the side of the pelvis. The inner surface is marked by a ridge, which represents the brim of the pelvis, and the portion of the bone above this point is known as the ala, or wing, and flares outward, forming the concavity of the iliac fossa. The inferior half of the bone extends downward to its junction posteriorly with the ischium and anteriorly with the superior ramus of the pubes. The chief anatomical features of the ischium are the body, which lies in the region of the acetabulum, the tuberosity, a greatly thickened prominence upon

which the body rests in the sitting position, and the ramus, which forms the inferior border of the obturator foramen and extends forward to join the inferior ramus of the pubes. The acetabulum is formed in part by all three portions of the innominate bone and is situated at their point of junction on the outer surface.

Ossification.—Ossification proceeds from three bony centres, one each for the ilium, pubes and ischium, which are well developed at birth. The rami of the pubis and ischium unite at about the age of eight years, and fusion of the three bones at their point of junction in the acetabulum occurs last and is seldom complete before the seventeenth or eighteenth year. Secondary centres of ossification for the iliac crest, the symphysis pubis, the anterior-inferior iliac spine, and the tuberosity of the ischium appear at about puberty, and, with the exception of that for the iliac crest, are united at about twenty.

FIG. 530.—Pelvis viewed from above. (Piersol: Human Anatomy.)

The latter is one of the last epiphyses to unite in the body and may persist to the twenty-fifth year or longer.

The Symphysis Pubis.—The pubic bones are very firmly united at the symphysis by a layer of fibro-cartilage, reinforced by the strong, partially-decussating fibres of the pubic ligaments. The joint is rather rudimentary and in many adults no synovial cavity is found. In the female during pregnancy a slight relaxation of the joint takes place, but ordinarily the union is solid, and fracture through the rami of the pubis occurs more frequently than separation of the symphysis.

The Sacro-iliac Joints.—The sacro-iliac joints are formed by the articulation of the lateral borders of the sacrum with the ilia. These are true joints, lined with articular cartilage, and containing synovial cavities. The sacrum is broader in front than behind, so that on horizontal section the joint line is oblique, running backward and inward. The surfaces are gently irregular, tending slightly to interlock. They are held together by the anterior, posterior, and superior sacro-iliac ligaments. The poste-

rior ligament is by far the strongest, as its function is to sling the sacrum and resist the tendency of the body weight, in the upright position, to force the sacrum forward into the pelvis. It comprises many layers of strong fibres, filling the gutter-like space between the posterior edge of the ilium and the surface of the sacrum. The normal motion at the sacro-iliac joints is slight and consists of rotation of the sacrum on a transverse axis, passing through the second segment. Normally, the antero-posterior diameter of the brim of the pelvis may be increased or lessened about 1 cm. by the extremes of this movement. Although the construction of the sacro-iliac joint appears weak, the strength of the posterior sacro-iliac ligament is such that in case of injury,

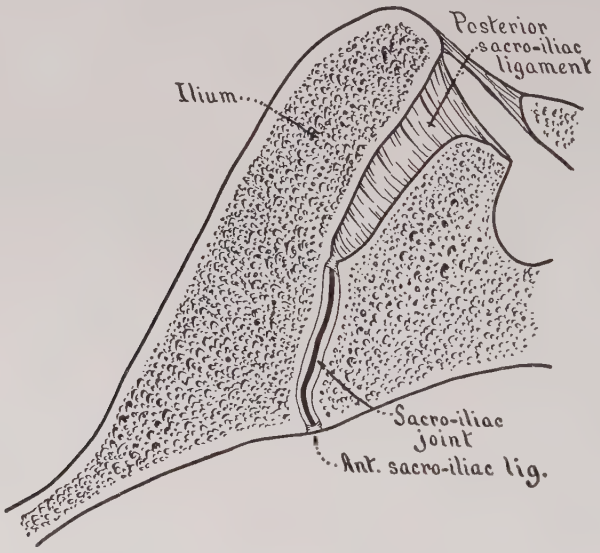


FIG. 531.—Horizontal section through the right sacro-iliac joint. Note its sloping direction backward and inward.

fracture of the ilium or sacrum at the point of attachment of the ligament is as apt to occur as rupture of the ligaments and true dislocation of the joint.

The Sacrosciatic Ligaments.—The sacro-iliac articulations are further reinforced by the two sacrosciatic ligaments, which pass from the lower edge of the sacrum across the space formed by the sacrosciatic notch to the ischium. The great, or posterior, sacrosciatic ligament arises by a broad base from the free border of the sacrum and coccyx and passes downward to be inserted into the tuberosity of the ischium. The lesser, or anterior, sacrosciatic ligament is situated in front of the greater, and arises from the edge of the sacrum and passes transversely across the notch to its insertion in the spine of the ischium. The two ligaments in conjunction with the edge of the innominate bone form the greater and lesser sacrosciatic foramina. Through the former pass the pyriformis muscle, the gluteal, sciatic, and internal pudic vessels and nerves, while through the latter are transmitted the obturator internus muscle and the internal pudic vessels and nerve.

TYPES OF PELVIC INJURY

Production.—Fracture of the pelvis is a fairly common form of injury and usually occurs as the result of severe violence, such as the passage of the wheel of a vehicle across the body, a fall from a height, a crush between two moving objects, as in a railroad collision, the fall of a heavy beam, or a mass of coal or rock. They are frequently multiple and, save

when produced by gunshot injury, are scarcely ever compound. They are of special importance as regards danger to life from the possibility of damage to the pelvic contents, which may be injured either by the violence itself, the forcible displacement of the bones, or by perforation from a sharp, pointed fragment.

Classification.—Many different types of injury may be produced, but they may be grouped under three general headings:

I. INJURIES OF THE PELVIC RING
   1. Fracture of the Rami of the Pubis
   2. Multiple Fractures of the Pelvic Ring
   3. Separation of the Symphysis Pubis
   4. Dislocation of the Sacro-iliac Joint

II. ISOLATED FRACTURE OF THE PELVIC BONES NOT AFFECTING THE CONTINUITY OF THE PELVIC RING
   1. Fracture of the Ilium
   2. Fracture of the Ischium
   3. Fracture of the Sacrum
   4. Fracture of the Coccyx

III. FRACTURES OF THE ACETABULUM

I. INJURIES OF THE PELVIC RING

By far the most serious type of injury that can affect the pelvis is the one which causes an interruption in the continuity of the pelvic ring. The pelvis has three functions: first, to bear and transmit the body weight; second, to support and protect the pelvic and abdominal viscera; and third, to provide a means of attachment for muscles. Fractures involving the integrity of the pelvic ring are apt to affect all three functions.

Mechanics of the Pelvis in Relation to Injury.—In studying the configuration of the pelvic ring, Humphry [1] points out that it presents five points of special weakness which are situated, at or a little external to, both sacro-iliac joints, at the symphysis pubis, and midway between the latter and the acetabula, and that these are the regions most likely to give way under the action of trauma. Morris,[2] analyzing the weight-bearing function of the pelvis, calls attention to the fact that structurally it is made up of a series of arches. Of these, only two are essential for weight-bearing, one for use when standing, and the other for use when sitting. In the standing position the body weight is transmitted from the sacrum to the femora through the femorosacral arch, which is represented by the strong mass of bone which forms the brim of the pelvis and extends from the upper edge of the acetabulum to the sacrum. When sitting, the weight is transmitted from the sacrum to the tuberosity

[1] Quoted by Piersol, *Human Anatomy*, p. 46.
[2] Morris, Henry, *Human Anatomy*, Philadelphia, 1895.

of the ischium through the ischiosacral arch, which corresponds to the thick mass of bone situated between these two points and passing through the posterior edge of the acetabulum. Considered from this point of view, Morris believes that the anterior portion of the pelvis functions as a tie or counter-arch to connect the weight-bearing arches and relieve them of strain. The reinforcement, thus provided, is so great that the main arches can be damaged only after the trauma has first injured the tie arch, and in this respect the theory is sustained by the clinical evidence—fracture through the rami of the pubis is the most common type of injury; frequently it is complicated by a second injury in the region

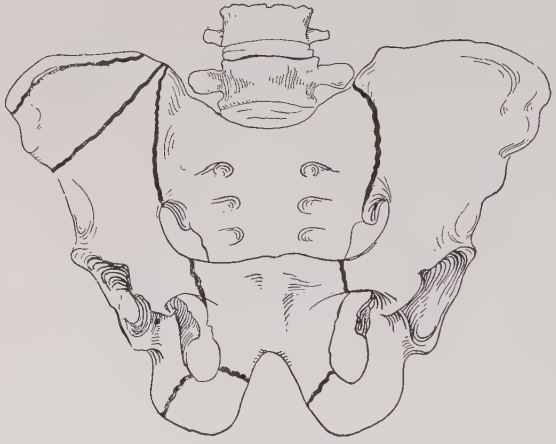


FIG. 532.—Drawing of pelvis showing common fracture lines.

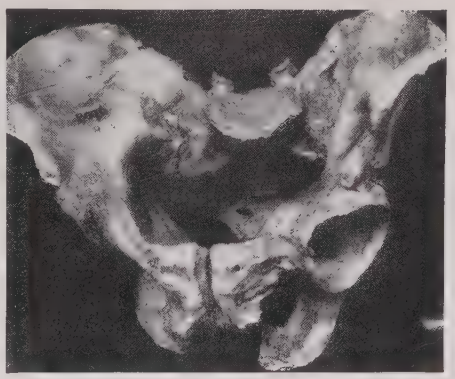
of the sacro-iliac articulations, but almost never does the latter injury occur alone.

Mechanism of Injury.—The pelvic ring is fractured only as the result of severe violence acting usually in a direct manner. When a force of crushing character is exerted on the pelvis in the antero-posterior direction, one or the other of the pubic bones fractures through the rami, and the support of the tie arch is lost. If the force continues to act, the strain comes to bear upon the main weight-bearing arches, which tend to open out until one or both give way. When the violence is applied to the pelvis in the lateral diameter, the pubic bone is first fractured by indirect violence, and the pressure then falls on the posterior arches, these being forced inward until fracture takes place. In the case of force transmitted upward through the femora, as from a fall upon the feet, fracture of the acetabulum is the most likely result, but in certain cases the pelvic ring may be involved instead, and in this instance it is again the pubic bone which gives way, and in rare cases there may be an associated injury of the posterior part of the pelvis.

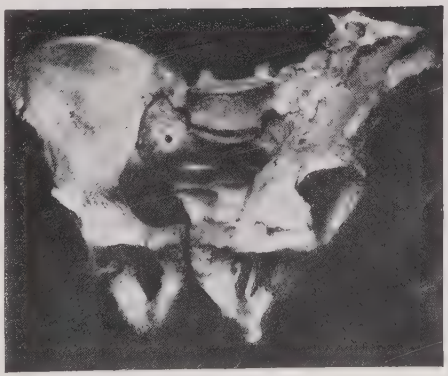
Fracture of the Pubis.—It will thus be seen that fracture of the pubic rami is the most common of the injuries involving the pelvic ring. The fracture is usually complete and either involves both the superior and inferior rami of the pubes, or one of the pubic rami and the ramus of the ischium. Displacement, if present, is usually slight. Comminution is not infrequent, in which case there may be considerable displacement of one of the fragments. Occasionally, both pubic bones may be fractured vertically, in which case, there is apt to be backward displacement of the middle fragment, which includes the symphysis.

Multiple Fractures of the Pelvis.—Fractures of the pelvic ring are frequently of multiple character and consist usually of a fracture of the pubic rami associated with a second injury in the neighborhood of the sacro-iliac joint, either on the same or the opposite side. The posterior injury is most commonly a vertical fracture of the ilium close to the sacral border, the fracture line passing downward to the sacrosciatic notch; a longitudinal fracture of the sacrum or a gross dislocation of the sacro-iliac joint is less common. A fairly frequent form of injury is the double vertical fracture of Malgaigne, which involves the rami of the pubes and ischium in front and the ilium near the sacro-iliac joint behind and on the same side. In such cases the acetabulum-bearing portion of the innominate bone constitutes a large middle fragment, and this may be displaced upward in toto,

533



534



535

FIGS. 533, 534 and 535.—Specimens illustrating various types of fractures of the pelvis. (533) Fracture of pubic rami. (534 and 535) Old healed specimens of multiple fracture. (Warren Anatomical Museum.)

giving rise to an appearance of shortening of the leg. In the majority of cases of multiple fracture the displacement is slight or entirely absent.

Separation of the Symphysis.—Separation of the symphysis pubis is of less common occurrence than fracture of the rami, of which it is to be considered a variant. It may be produced in exactly the same manner, the bone in this case proving more resistant than the pubic connection, or it

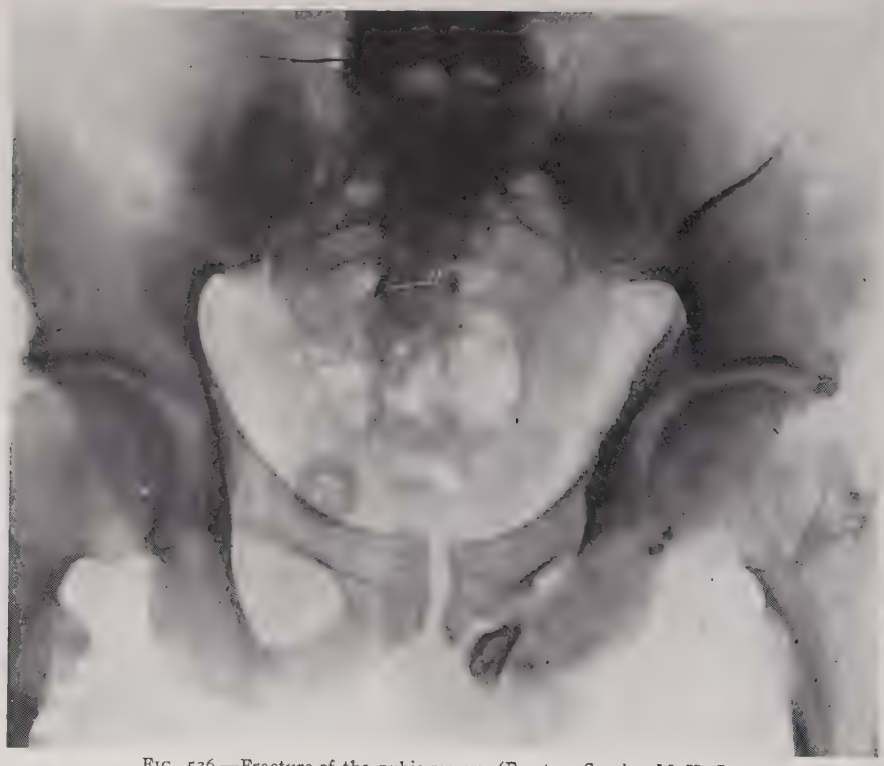


Fig. 536.—Fracture of the pubic ramus. (Fracture Service, M. H. G.)

may result from forced abduction of the thighs or in parturition. The injury is frequently part of a multiple lesion and may be associated with a posterior fracture of the ilium or more commonly a sacro-iliac luxation. Following the injury, the two pubic bones may spring together again and no displacement persist, but more frequently they are considerably displaced. This may take the form of a wide horizontal separation, a gap of 5-10 cm. intervening between the bones, or it may consist of an upward displacement of one bone with respect to the other. Pubic displacement cannot occur without some degree of injury to the posterior pelvic arch and, in the absence of a fracture in this region, is of itself to be regarded as evidence of a sacro-iliac luxation.

Sacro-iliac Dislocation.— The possibility of dislocation of the sacro-iliac joint as a part of a multiple pelvic injury has been mentioned above. The lesion occurs as a variant of fracture of the posterior border of the ilium and is particularly likely to follow a crush in the antero-posterior direction, which tends to open out the posterior arches of the pelvis, the strong posterior iliac ligaments not providing protection from this mech-

FIG. 537.—Fracture of the pubis and ischium. (Fracture Service, M. G. H.)

anism. In addition, rupture of the sacro-iliac ligaments and complete dislocation has been produced by a fall from a height without other demonstrable injury of the pelvis, although doubtless such an accident is always accompanied by a subluxation of the symphysis, which does not show. This is, however, an infrequent form of injury.

Associated Injury of the Pelvic Contents.— Injury to the urethra and bladder are frequent complications of these fractures. Less commonly, the vagina, the rectum, and the iliac blood-vessels are damaged.

Injury of the Urethra.—Injury of the urethra by a displaced fragment of bone affects usually the membranous, and less commonly, the prostatic portion of the urethra. Occasionally the urethra is torn away from the bladder. There is usually some degree of shock, and swelling, pain, tenderness, and discoloration make their appearance in the perineum. When the bulbous portion of the urethra is ruptured, escape of blood from the meatus may be the only positive sign present. There is a strong desire to pass urine and the patient being unable to start the act of mic-

turition as a rule, the bladder becomes distended. When the posterior urethra is torn, there is usually no bleeding from the meatus.

Urinary Extravasation.— Should the patient succeed in passing urine and meet with resistance from a tear of the urethra, extravasation of urine takes place. When it occurs through or in front of the anterior layer of the triangular ligament, the urine infiltrates the anterior part of the perineum, the scrotum, penis, groins and anterior abdominal wall. It is confined by the attachment of the perineal fascia to the base of the triangular ligament and by the attachment of the deep layer of the superficial fascia of the abdominal wall to the fascia lata of the thigh. In rupture of the posterior urethra, if the posterior layer of the triangular ligament is torn, the urine infiltrates the cellular tissue around the neck of the bladder and passes upward on to the anterior abdominal wall between the fascia transversalis and the parietal peritoneum. With the occurrence of extravasation the patient experiences a burning pain in the scrotum and perineum.

FIG. 538.—Comminuted fracture of pubis. (Fracture Service, M. G. H.)

Treatment.— The patient should be dissuaded from making attempts to pass urine, lest extravasation occur. A soft rubber catheter is passed along the urethra. Should it enter the bladder it should be left in for a week and connected with a drainage bottle. It is often impossible to pass a catheter even under an anæsthetic and this, along with the fact that the flow along the catheter is apt to be interrupted by blood-clot, makes it nearly always necessary to perform perineal section. If extravasation has taken place, perineal section must be done at once and multiple incisions made through the area of extravasation.

Rupture of the Bladder.— Intraperitoneal rupture of the urinary bladder is nearly always the result of violence applied to the anterior abdominal

wall when the bladder is full. The tear, vertical or oblique, is usually situated at the highest part of the posterior wall. The urine escapes into the general peritoneal cavity and the bladder collapses. Unless dealt with

FIG. 539.—Separation of the symphysis pubis, combined with fracture of iliac crest. (Fracture Service, M. G. H.)

promptly, death results from a combination of peritonitis and urinary poisoning.

Extraperitoneal rupture may occur either in the presence of a full or an empty bladder. The usual variety of extraperitoneal rupture of the bladder associated with fracture of the pelvis, and the variety most commonly met with when the bladder is empty, is situated in the anterior

wall near the neck of the bladder. It may be produced either by fracture of the pubis with posterior displacement of a fragment or by separation of the symphysis with direct pressure by the body of the bone. Bartel's statistics, based upon 149 cases of injury of the urinary bladder, show the cause to have been fractures of the pubis in 31 cases and separation of the symphysis in 22 cases. The urine escapes into the cellular tissue around

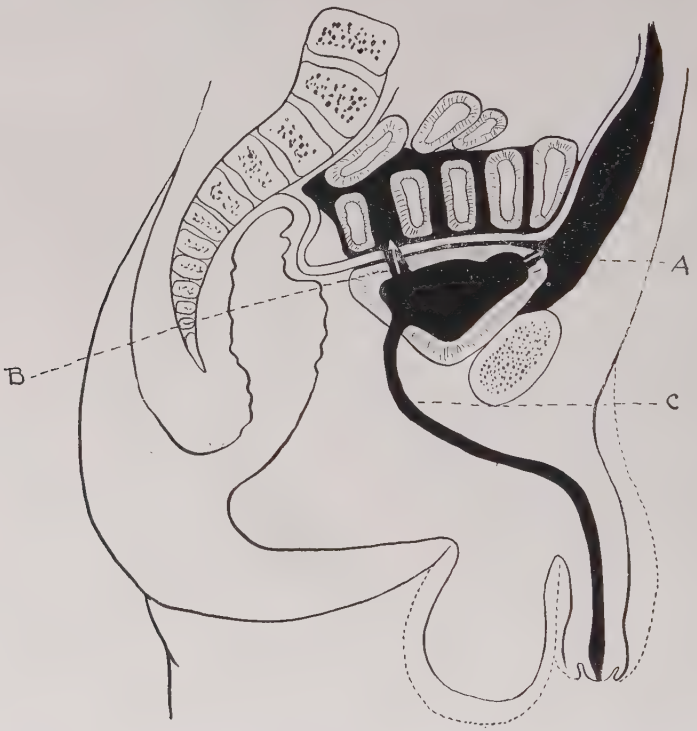


Fig. 540.—Sagittal section through pelvis, showing relation of bladder to pelvis, and the common points of bladder injury. (A) Extraperitoneal rupture. (B) Intraperitoneal rupture. (C) Point of urethral injury. (Modified from Keene's Surgery.)

the neck of the bladder and may ascend towards the abdominal wall or collect to form an accumulation between the bladder and rectum.

Pain and tenderness are present above the pubis. The patient has a great desire to pass urine but is unable to do so. A catheter passes easily into the bladder, but only a few drops of blood-stained urine escape, although the patient may not have passed urine previously for many hours. If a rigid instrument is employed, the fact that the bladder is collapsed may be inferred from the fact that the point of the instrument is not able to move about freely. In cases of intraperitoneal rupture, a fullness in the pouch of Douglas may be detected per rectum and an ill-defined dullness in the flanks. In cases of extraperitoneal rupture, the

first signs may be tenderness and a well-defined dullness above the pubis. Rupture of the bladder not infrequently escapes recognition.

Treatment aims at closing the rent in the bladder and in providing drainage for the escape of extravasated urine before infection becomes established.

Association with Other Skeletal Injuries.—Because fractures of the pelvis commonly result from severe forms of violence, it is important to remember that they are frequently associated with other serious skeletal injuries which may involve the skull, the spine, or the extremities. If the patient is unconscious, it is possible to overlook one or other of the lesions, and this point has lately been emphasized by two cases seen by one of the

FIG. 541.—Fracture of the pelvis. Recumbent treatment on Bradford frame. Note pelvic swathe and flexed position of knees.

writers. In both there had been a severe head injury, and this feature had apparently so dominated the original clinical picture that the presence of associated pelvic fractures, in one consisting of a central dislocation of the head of the femur, had not been recognized until several months later.

Diagnosis of Pelvic Fractures.—The diagnosis of fracture of the pelvis is based upon a history of severe violence acting in the region of the pelvis, the localization of pain in that area, increased by movement, and the local evidence of the effects of trauma. As displacement is usually slight or absent, inspection and palpation commonly fail to reveal deformity. In the case of separation of the symphysis, a centrally situated depression may be noticed, and in the case of a double vertical fracture, upward displacement of the middle fragment may be detected. Pain and tenderness are present over the seat of fracture and are referred there also on pressing together or on separating the iliac crests. Abnormal mobility and crepitus may be accidentally demonstrated, but no special effort should be made to elicit them on account of the risk of injuring soft structures. Pressure directed upward on the leg will frequently produce pain at the

site of fracture. Digital examination by rectum may reveal irregularities in the bony contour and abnormal position of the fragments. An area of ecchymosis above the inguinal ligaments is suggestive of fracture of the pubes, while ecchymosis, swelling, and tenderness in the sacro-iliac region indicate the presence of a dislocation or fracture of the posterior portion of the ilium, as likewise does pain referred along the distribution of the sciatic nerve. Signs pointing to visceral injury serve also

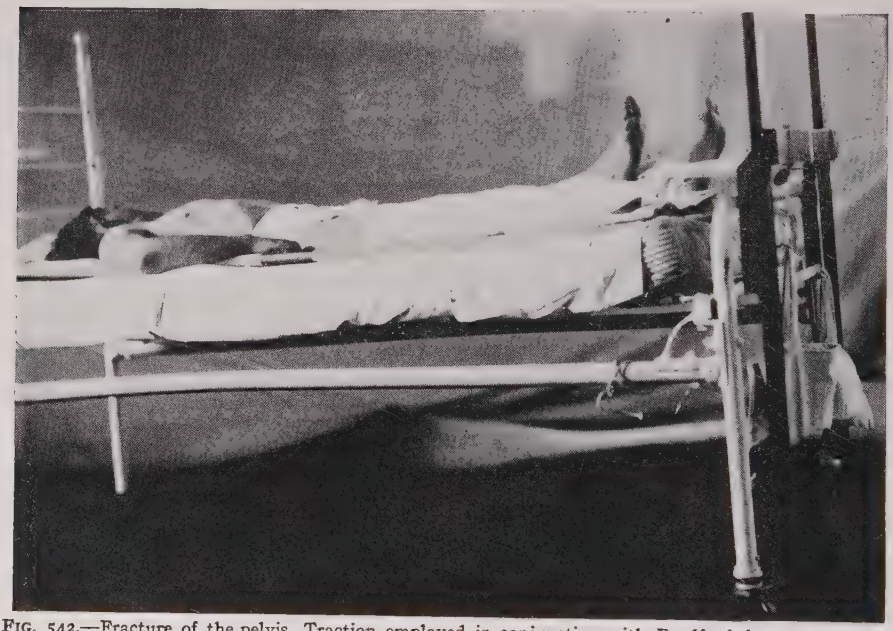


FIG. 542.—Fracture of the pelvis. Traction employed in conjunction with Bradford frame as required in some cases of fracture of the pelvis.

as presumptive evidence of the presence of fracture. In the last analysis, however, the main evidence upon which the diagnosis is based, and particularly as regards the character of the fracture, is derived from roentgenological examination.

Prognosis.— The prognosis depends in large measure upon the nature of the fracture and the character of the trauma. In an active fracture service in a general hospital situated in a large city, we have been struck by the extreme rarity of visceral complications and other severe features in a large number of cases of fractured pelvis, and this would lead us to suppose that the reputation for seriousness which this injury has acquired is unmerited. On the other hand, reports from mining localities present figures indicating quite the reverse experience, and it is, therefore, fair to suppose that a difference in the character of the violence is the determining factor. In uncomplicated cases, the prognosis as regards life

is good. Union is usually solid in from eight to ten weeks, and delayed union or failure of union are of rare occurrence, if they occur at all. Complete functional recovery may be expected in the great majority of cases so long as the acetabulum is not involved by the injury. A very striking feature in the experience of the writers is the absence of disability even in the presence of severe, unreduced displacement, such as wide gaping of the symphysis pubis and dislocation of the sacro-iliac joint. Such injuries may necessitate the wearing of a suitable belt support, but frequently give rise to no symptoms.

Treatment.—Treatment has for its aim the replacement of the fragments, when possible, their maintenance in the corrected position until union is complete, and the care of attendant shock or complicating visceral injuries, when these are present. The latter constitute the urgent indications for treatment, and considerations affecting the fracture itself are of secondary importance until these conditions have been remedied. If the patient is seen at the place of injury, he should be gently lifted on a stretcher, the knees bandaged together, and the body fastened securely to prevent movement during transportation to the nearest hospital. This must be managed with great care lest fragments become displaced and injure the viscera. At the first possible moment the matter of visceral damage should be investigated by analysis of the patient's symptoms, palpation of the abdomen, and examination of the specimen of urine, catheterization being employed in the event of inability to void or the presence of hæmaturia.

Fractures without Displacement.—Pelvic fractures without displacement require fixation only, and this may readily be obtained by placing the patient in dorsal decubitus on a Bradford frame, with a pillow under the knees to relieve the drag of the extremities upon the pelvis, the knees being loosely bound together for the first week. The pelvis should be supported by the use of a webbing belt encircling the body just above the level of the trochanters and drawn firmly together in front by appropriate straps and buckles. Perineal straps are necessary to retain the belt in position. If such a belt is lacking, a broad strip of adhesive plaster may be applied to the pelvis, the ends being brought around in front and doubled back on themselves to provide a firm support for the insertion of a lacing of bandage or other material which is used to tie them together tightly in front of the pubis. If the plaster is properly protected with gauze, there is no difficulty encountered from adherence of the pubic hair.

Fractures with Displacement.—When the fracture is accompanied by displacement, the attempt should be made to correct the deformity, and the various measures indicated depend upon the character of the injury. In the event of wide gaping of the symphysis or of similar displacement in a fracture of the rami of the pubes, a broad canvas sling or hammock

should be passed under the pelvis and low back, and the ends secured to the overhead beams of a Balkan frame. The pressure of the sling on the sides of the pelvis, from the weight of the patient's body, exerts a strong compressing force on the bones, which tends to push them together. With this apparatus the Bradford frame is unnecessary, and the nursing care is facilitated by suspending the ends of the hammock by means of weights and pulleys so that the patient may be lifted readily

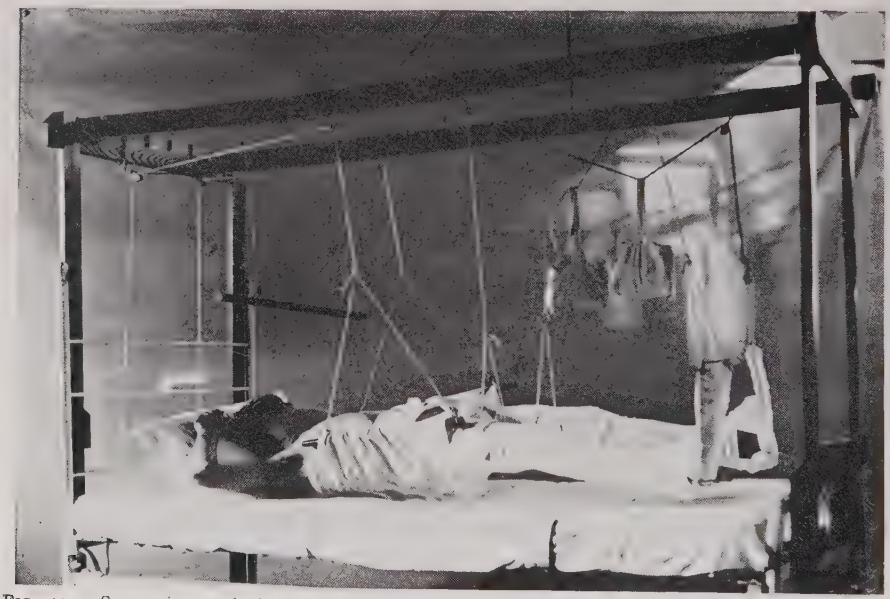


FIG. 543.—Suspension method indicated in cases of extensive fracture of the pelvis. Note suspension of legs by Cabot splints, traction being applied to the ends of the splints.

when this is necessary. The general comfort is promoted and the deformity more easily corrected if, at the same time, the legs are suspended in Cabot's posterior wire splints and counterpoised appropriately with weights and pulleys (Fig. 543), in order to relieve the pelvis of the strain which their weight imposes.

Traction.—Upward displacement of one of the pubic bones at the symphysis may be corrected by the application of continuous extension to both legs. In this case the patient should be placed on a Bradford frame and counter-traction obtained by the use of a swathe encircling both frame and pelvis and retained in position by perineal straps, and for greater security the foot of the bed should be elevated. Heavy extension amounting to 35 to 50 pounds for the individual legs is at first necessary.

Manipulative Reduction.—Manipulative reduction is decidedly unsafe, but may be attempted on occasions when other methods fail, and particularly in the case of sacro-iliac luxation with displacement. In the latter

type of injury, the manœuvre consists in flexing the leg at the hip with the knee extended and then making pressure posteriorly in the axis of the limb, while at the same time the other leg is held in the extended position, and lateral compression is applied to the sides of the pelvis. First one and then the other leg is manipulated, and the reduction may accompany either movement, depending upon the type of the displacement. Direct pressure and counter-pressure upon the ilium and sacrum are also effective.

FIG. 544.—Pelvic belt required in convalescent treatment of fracture of the pelvis.

Owing to the situation of these bones in relation to the sacro-iliac joint and to their accessibility, a nearly perfect system of levers is available for reduction of a dislocation. Thus, if the upper portion of the sacrum were displaced forward on the left side, replacement would be obtained by pushing forward with one hand on the lower portion of the sacrum while with the other hand exerting counter-pressure on the posterior superior spine of the left ilium. Either a pelvic belt or the method of suspension in a pelvic hammock (Figs. 541-543), may be employed to retain the bones in position, and the latter method of itself is capable of causing reduction in certain cases.

After-treatment.—Corrective apparatus such as extension, hammock suspension, or suspension of the legs, when used, should be continued for a period of two to four weeks, at the end of which time it may be removed and greater freedom, particularly in the use of the legs, permitted.

Recumbency should be maintained for six to ten weeks, depending upon the type of fracture and the presence or absence of displacement. A well-fitted pelvic belt or corset gives great comfort and protection during the early period of ambulatory treatment and may be used with advantage for several months. Complete recovery should usually be obtained in three to four months.

Operative Measures.—Operative treatment is rarely indicated, particularly if the proper corrective measures are applied at an early period when

545

546

FIGS. 545 and 546.—Anterior and posterior view of abdominal or pelvic belt, useful in sacro-iliac and low lumbar injuries.

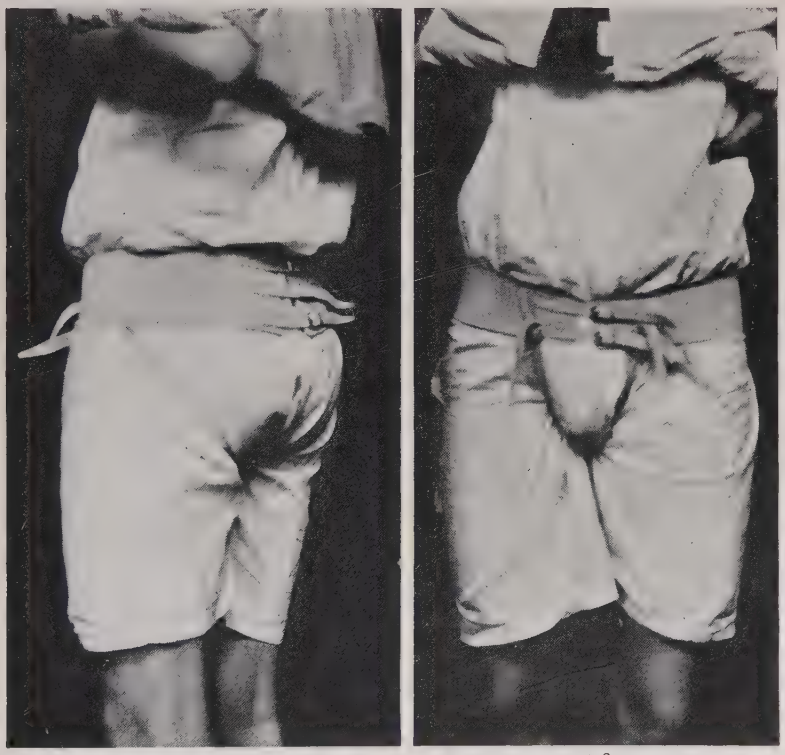
the fragments are still mobile. Cases have been reported in which reduction by the open method has been accomplished in separation of the symphysis, the bones being approximated and secured by wire loops passed around the descending rami and fastened to each other. Good results from the operative method have been reported in cases of sacro-iliac dislocation with displacement, the gap between the sacrum and ilium having been filled by the insertion of a bone graft.

II. ISOLATED FRACTURE OF THE BONES OF THE PELVIS NOT AFFECTING THE CONTINUITY OF THE PELVIC RING

1. FRACTURES OF THE ILIUM

Fracture of the Ala.— The wing of the ilium is not infrequently fractured transversely, as a result of the action of direct violence, without involvement of the pelvic ring. An irregular, comminuted type of frac-

ture is produced, which starts at the iliac crest and runs for a varying distance into the iliac fossa. Displacement of the fragments is usually slight, being prevented by the extensive muscle attachments. Locally there is pain and tenderness, and abnormal mobility is readily demonstrated. The injury is rarely serious of itself, but is frequently associated with other injuries. Visceral damage may result from the direct action of the violence, but is seldom due to the displacement of the bones. The



547 548

FIGS. 547 and 548.—Pelvic belt of leather; useful following pelvic injuries.

injury is quite painful, and recumbent treatment is necessary with moderate flexion of the hips secured by a pillow under the knees to relieve muscle strain. A local strapping of adhesive plaster or a firm spica bandage gives considerable relief. Union takes place rapidly and is usually solid in four to six weeks.

Separation of the Iliac Crest.—The whole or a part of the crest of the ilium may be separated. Before the age of eighteen to twenty this amounts to a partial epiphyseal separation. The treatment is practically the same as in fracture of the ala, but during the first week or two the comfort of the patient may be promoted and strain on the separated fragment

relieved by a position with the shoulders elevated and the spine moderately flexed, which relaxes the muscles attached to the crest.

Fracture of the Iliac Spines.— Corlette [3] has reported a case in which the anterior superior spine was torn off by muscle violence, in all probability

FIG. 549.—Specimen illustrating fracture of the crest of the ilium. (Warren Anatomical Museum.)

due to the action of the sartorius. The anterior inferior spine may be avulsed by traction exerted through the ilio-femoral ligament. In treatment the thigh should be flexed to secure relaxation of the muscles, and it may be necessary to replace the fragment by the open method, fixation being secured by suture or the insertion of a bone peg.

2. ISOLATED FRACTURE OF THE ISCHIUM

This injury is produced by a violent fall in the sitting position, and the entire bone or only the tuberosity may be fractured. Considerable comminution is usually present, and occasionally the injury is compound.

[3] C. E. Corlette, *Australian Med. Gazette*, March 15, 1895, p. 99.

Displacement, if present, is slight, and reduction is not indicated. Recumbent treatment is necessary only in the severe cases, simple fixation by a plaster spica with the hip extended and the knee flexed (to relax the

FIG. 550.—Fracture of the crest of the ilium. (Fracture Service, M. G. H.)

hamstrings) being usually sufficient, in which case walking with crutches may be permitted from the beginning.

3. ISOLATED FRACTURE OF THE SACRUM

A transverse fracture of the lower portion of the sacrum, either below the level of the sacro-iliac joints or extending into their inferior borders, is occasionally produced by a severe fall or blow upon the lower portion

of the spine. With very severe violence the lower fragment may be displaced forward into the pelvis with damage to the rectum, or the sacral nerves may be implicated with resulting paralysis of the bladder, rectum, and lower limbs. At the same time the soft parts over the sacrum are bruised, and the fracture may be compound or comminuted. In other cases displacement may be entirely absent or slight. Simple recumbent treatment for two or three weeks is alone required in the latter type of injury, but in the complicated cases, operative treatment with removal of the depressed fragments, repair of the rectum, and freeing or suturing of the nerves would be indicated, depending upon the extent of the damage.

4. ISOLATED FRACTURE OF THE COCCYX

Although fracture of the coccyx undoubtedly occurs, as the result of direct violence from a fall or blow, it is important to remember that the majority of cases in which this diagnosis is made in reality represent other conditions, usually affecting the low spine, in which pain is referred to this area by involvement of the posterior primary divisions of the nerve roots and the posterior sacral plexus. Excision of the coccyx has been performed in a large number of these cases of coccygodynia with failure to obtain relief. If the lesion in reality represents a fracture—and one may interpolate here that a history of trauma is obtainable from almost every patient who complains of pain in the region of the coccyx—it is fair at least to try the effects of strapping the pelvis with adhesive plaster and of wearing a properly fitted corset or belt before proceeding with the excision. A roentgenogram offers the best means of diagnosis.

III. FRACTURES OF THE ACETABULUM

While fractures involving the acetabulum must necessarily be included in the list of injuries of the pelvis, they are of importance chiefly as they affect the function of the hip, and for this reason will be considered in the section dealing with injuries in the region of the hip-joint (see p. 472).

CHAPTER XIV

INJURIES OF THE HIP

I. DISLOCATION OF THE HIP
II. FRACTURE OF THE ACETABULUM WITH INTRAPELVIC DISPLACEMENT OF THE HEAD OF THE FEMUR
III. SEPARATION OF THE CAPITAL EPIPHYSIS OF THE FEMUR
IV. FRACTURE OF THE NECK OF THE FEMUR
V. INTERTROCHANTERIC FRACTURE OF THE FEMUR
VI. PERTROCHANTERIC FRACTURE OF THE FEMUR
VII. FRACTURES OF THE TROCHANTERS

ANATOMY OF THE HIP

THE hip is one of the strongest joints in the body, notwithstanding the fact that it permits a greater range of motion than almost any other articulation with the exception of the shoulder. Its stability is derived partly from the ball-and-socket principle, on which it is constructed, and also from the strength of its ligaments.

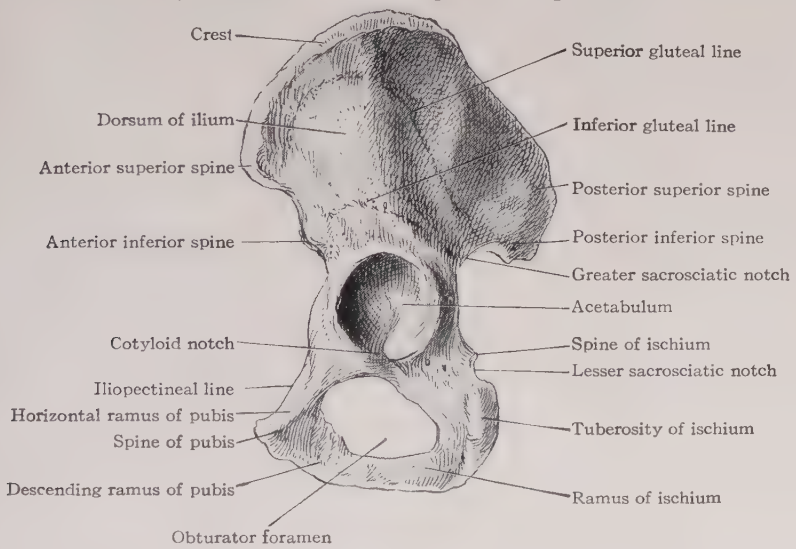
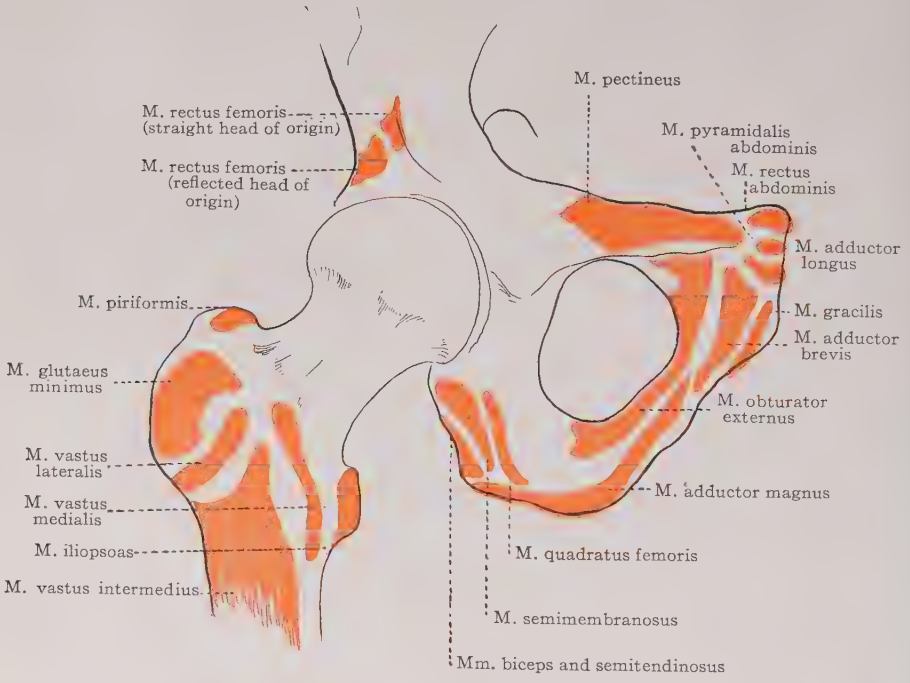


FIG. 551.—The bony relations of the acetabulum. (Davis: Applied Anatomy.)

The Acetabulum.—The acetabulum consists of a hemispherical fossa about one and one-half to two inches in diameter, with a circular rim which is raised above the surface of the pelvis. The rim is interrupted by a gap at its lower edge known as the cotyloid notch. The inner surface of the acetabulum is lined with articular cartilage except for the quadrant lying above this notch, which, in life, is filled with fat and serves as a receptacle for the ligamentum teres. The acetabulum is further deepened by the addition of a cartilaginous rim known as the cotyloid ligament, which clasps the globular head of the femur and helps to retain it in position. The acetabulum is situated on the summit of a bony ridge which extends from the anterior superior spine of the ilium to the tuberosity of the ischium and which divides the external surface of each half of the pelvis into two planes: an anterior one, composed of the ischium and pubis,

sloping forward and inward, and a posterior one, consisting of the ilium, sloping backward. The obturator foramen lies in front of and below the acetabulum.

The Upper Extremity of the Femur.—The upper extremity of the femur consists of the head, neck, and trochanters. The neck forms an obtuse angle with the shaft and slopes upward, inward, and slightly forward. There is considerable variation in the size of this angle, but the average is about 125 degrees. The forward inclination of the neck is about 12 degrees and its average length about 4 cm. The neck narrows



552

FIGS. 552 and 553.—Outline drawing of the upper end of the femur and the innominate bone to show the points of origin and insertion of the muscles of the hip. (552) Anterior view. (553) Lateral view.

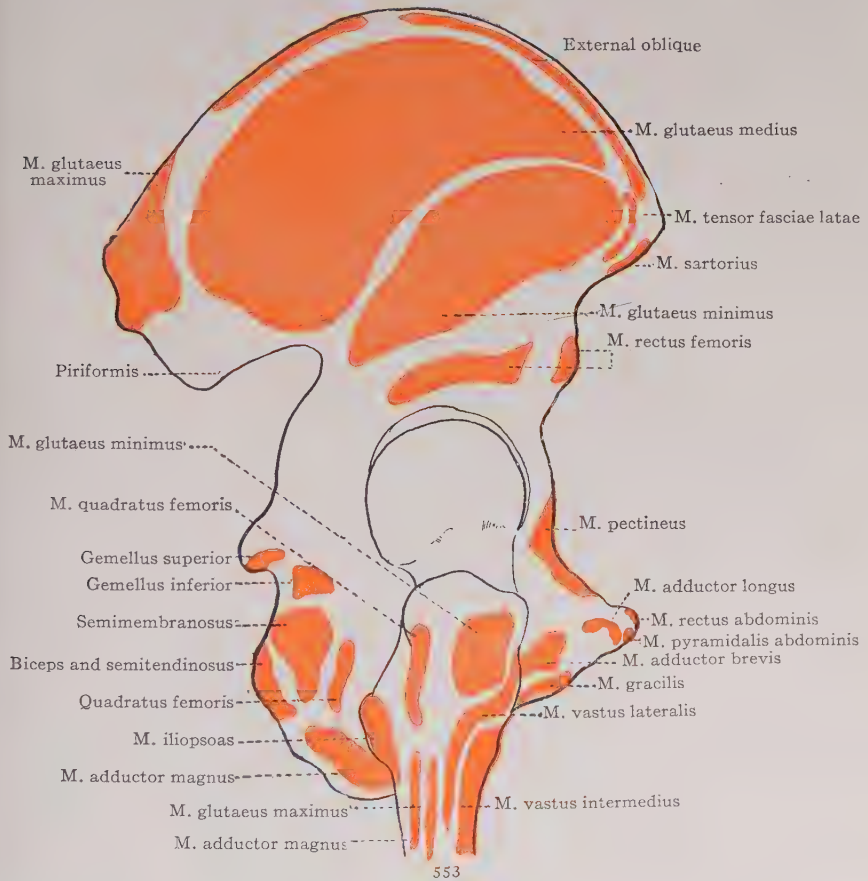
as it extends upward from the base and terminates in the head. The latter is spherical and everywhere covered with articular cartilage except for a small depression slightly below the centre, where the ligamentum teres is attached.

Alteration in the angle formed by the neck with the shaft is a frequent result of injury to the head or neck of the femur. Flattening of the neck or decrease in the angle is known as coxa vara, while the reverse condition, with an increase in the angle, is known as coxa valga. The former is by far the more common, and by causing shortening of the leg and mechanical interference with certain movements, it results almost always in a certain amount of disability.

The base of the neck joins the shaft of the femur at the trochanteric region. The greater trochanter projects upward above the neck in the line of the shaft. The lesser trochanter forms a rounded knob situated on the mesial side of the posterior surface of the shaft just below the neck. The two trochanters are joined by the intertrochanteric line in front and the prominent intertrochanteric ridge behind. The digital fossa is the hollow lying between the greater trochanter and superior surface of the base of the neck.

Ossification of the Femur.—The osseous development of the upper portion of the femur proceeds from three centres, one for the head, and one for each of the trochanters. The former is of main surgical importance, being concerned with the growth of the

neck and shaft, while the two latter, having to do only with local development, are of comparatively slight interest. The centre for the head appears the latter part of the first year and unites from the seventeenth to nineteenth years. The epiphyseal cartilage has the shape of an excavated hemisphere and forms a cap for the proximal end of the neck, but its position with respect to the latter varies considerably in different individuals. In some cases the epiphyseal line is nearly horizontal, while in others it is nearly vertical. In the latter case it would seem that separation could occur



553

more readily than in the former. The centres for the trochanters appear at rather variable times, that for the greater trochanter first (three to six years) and the one for the lesser trochanter last (eight to fourteen years), and they unite slightly later than the centre for the head.

Ligamentum Teres.—The spherical head fits snugly in the acetabulum and is retained in position by the clasp of the cotyloid ligament, which extends beyond its greatest circumference. The ligamentum teres arises from the sides of the cotyloid notch and runs upward in the acetabulum, being covered with synovial membrane, and is inserted in the depression on the head of the femur. In early life it serves to transmit blood-vessels to the head, but in later years these vessels usually disappear, and blood supply from this source is negligible. Normally, it is not under tension, and its chief function seems to be to distribute the synovial lubricating fluid about the joint.

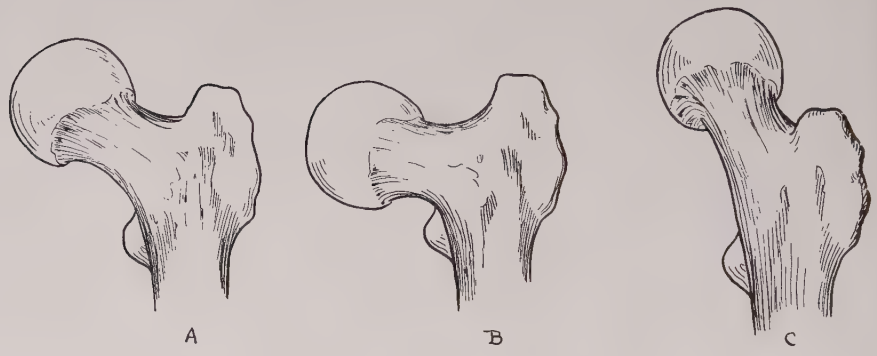


FIG. 554 (A, B, C).—View showing variations in the angle of the neck. (A) Normal angle. (B) Coxa vara. (C) Coxa valga.

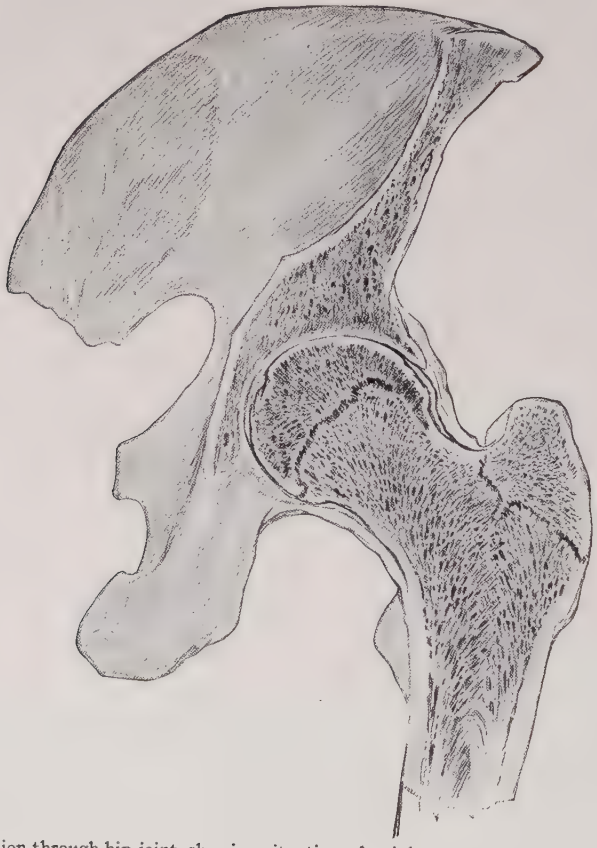


FIG. 555.—Section through hip-joint, showing situation of epiphyses of the upper end of the femur. (Piersol: Human Anatomy.)

The Capsule.—The capsule arises from the cotyloid ligament and the margin of the acetabulum and extends downward as a tubular covering for the head and neck. The anterior portion is attached to the femur along the intertrochanteric line and is

much longer than the posterior portion, which is attached to the neck about midway between the head and trochanter. This difference between the anterior and posterior attachments is of great importance in relation to fracture of the neck of the femur. The central fragment is dependent for blood supply upon vessels reaching it through the capsule, and some capsular attachment is likely to be preserved in all but those cases where the fracture line passes just below the head (Fig. 604). The head and neck of the femur are nourished also by the thick vascular periosteum and by strong fibrous bands reflected on to the neck from the attachments of the capsule, the so-called retinacula or cervical ligaments of Stanley. In fractures of the neck of the femur which present little or no displacement, the integrity of these ligaments plays a part in determining union by maintaining the blood supply to the proximal fragment.

The Ilio-femoral Ligament.—The strongest ligament of the hip-joint and, in fact, of the entire body is the ilio-femoral or "Y" ligament of Bigelow. Its fibres arise from the ilium in the space between the anterior inferior spine and the upper margin of the acetabulum and pass downward in a fan-shaped manner. The outer and inner portions are considerably stronger than the middle, so that they form divergent limbs like the letter "Y," which are inserted respectively in the upper and lower portions of the inter-trochanteric line close to the greater and lesser trochanters. The posterior portion of the capsule is reinforced by the pubo-femoral and ischio-femoral ligaments but is much less strong than the anterior portion.

The arrangement of the "Y" ligament is such that either or both of its limbs are placed under tension by every motion of the hip save that of flexion. It, therefore, has an important function in checking extremes of movement. It is relaxed only by flexion of the hip, and this motion is checked by contact of the front of the thigh with the abdomen.

Muscles of the Hip.—The muscles of the hip are also important factors in furnishing support to the joint. The iliopsoas passes directly over the front of the capsule to be attached to the lesser trochanter. It, and the rectus femoris, are the chief flexors. The short external rotators, consisting of the pyriformis, superior and inferior gemelli, internal and external obturators, and the quadratus femoris, pass laterally from the pelvis directly over the back of the joint to be attached to the femur in the region of the trochanters or below. The gluteus medius and minimus, passing downward from the side of the ilium to the tip of the greater trochanter, are the chief abductors. The tensor fasciæ femoris, passing obliquely downward and backward from the anterior superior spine, and the gluteus maximus, coming obliquely downward and forward from the posterior portion of the ilium, have a common insertion in the iliotibial band, and by exerting pressure on the outer surface of the trochanter hold the head firmly within the acetabulum and prevent its lateral displacement. Extension is chiefly the result of the contraction of the gluteus maximus and hamstring muscles.

Vessels and Nerves.—The femoral vessels lie directly anterior to the head of the femur and are an important guide in locating it by palpation. The femoral nerve lies to the outer side of the artery in Scarpa's triangle, but rapidly subdivides into small motor branches supplying the anterior thigh muscles. The adductor muscles are supplied by the obturator nerve, which reaches the thigh *via* the obturator foramen. The sciatic nerve passes over the neck of the femur posteriorly, being separated from the capsule by the short external rotator muscles.

EXAMINATION

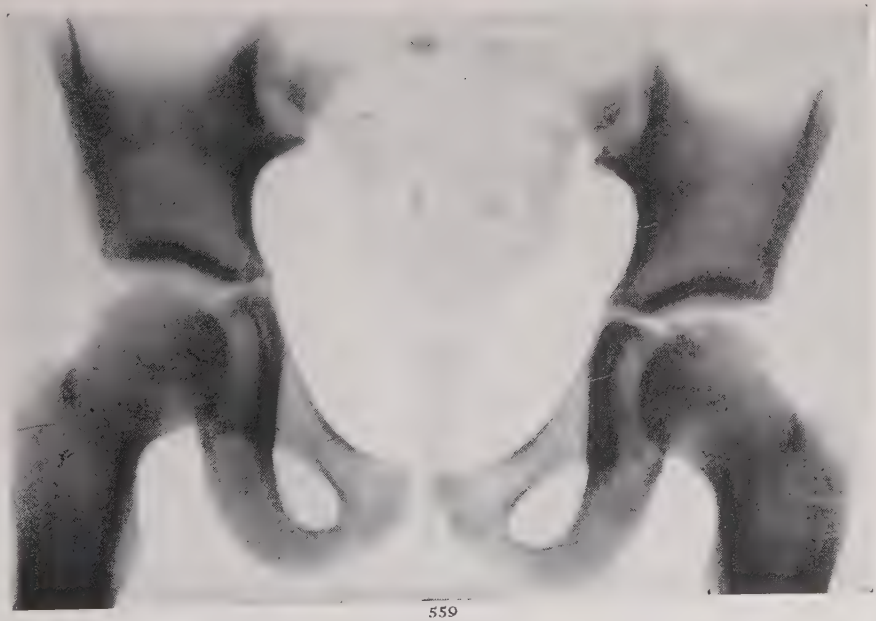
Bony Landmarks.—In examining this region, various bony landmarks are readily located by palpation. The anterior superior spine is the best point from which to measure the length of the legs, the internal malleolus usually serving as the opposing landmark. When measuring, care must be exercised to see that both anterior spines lie in the same transverse plane and that the position of the legs in relation to the pelvis

556

557

FIGS. 556, 557 —Development of the epiphyses of the upper end of the femur, and ossification of the pelvis. (556) Age of seven weeks. (557) Age of one year, one month.

558



559

FIGS. 558, 559.—Development of the epiphyses of the upper end of the femur, and ossification of the pelvis. (558) Age of four years, six months. (559) Age of six years, one month.

is the same. The end of the tape should be held against the inferior surface of the spine rather than astride it.

The anterior inferior spine lies about 5 cm. below the anterior superior spine. The symphysis pubis, crest of the ilium, and tuberosity of the ischium are other important landmarks. It is particularly important to be able to readily locate the tuberosity of

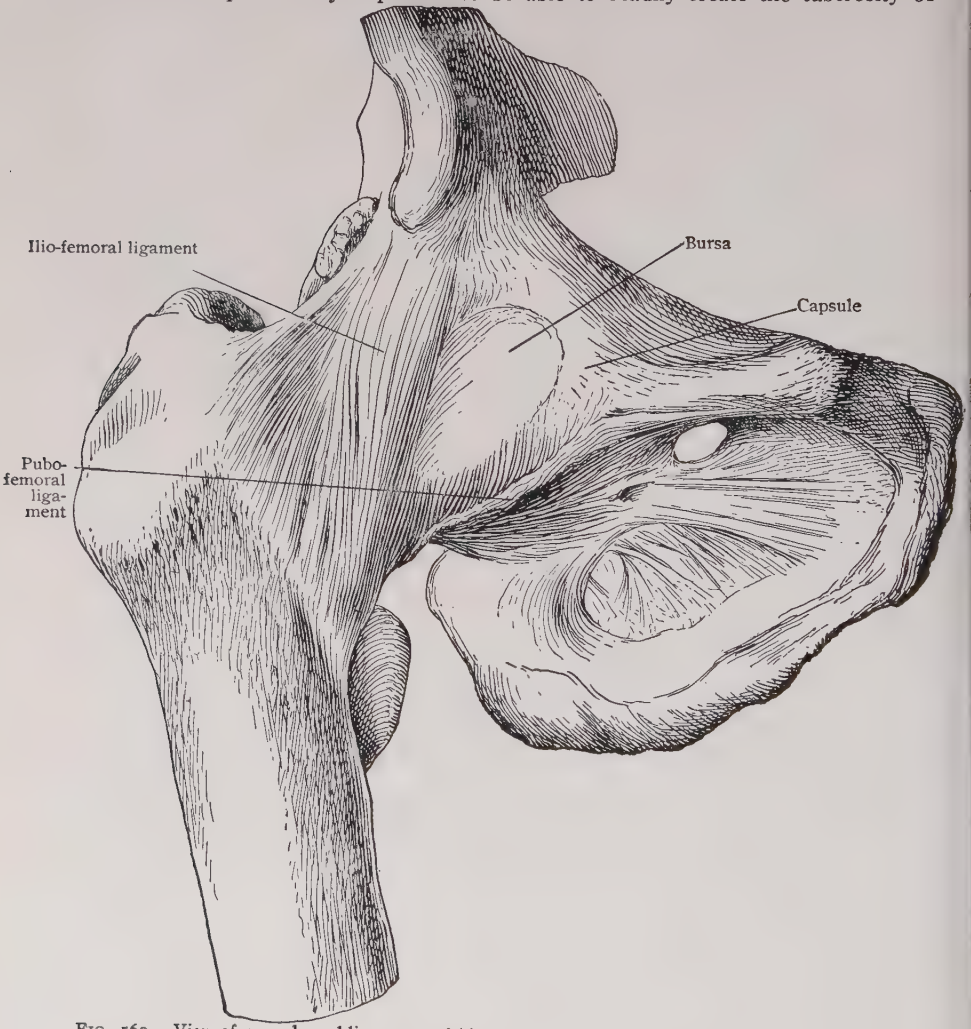


FIG. 560.—View of capsule and ligaments of hip, anterior aspect. (Piersol: Human Anatomy.)

the ischium, as this is the common bearing point for various traction splints which are used in the treatment of fractures of the femur. The greater trochanter is most readily palpated at its upper, posterior margin, although in thin people it may be prominent throughout.

Normal Relations.—The normal relations of the bony landmarks are of considerable importance, as their position may be altered by injury, and this provides a means of diagnosis. Nélaton's line refers to a line drawn from the anterior superior spine to the tuberosity of the ischium. Normally it passes through the tip of the greater

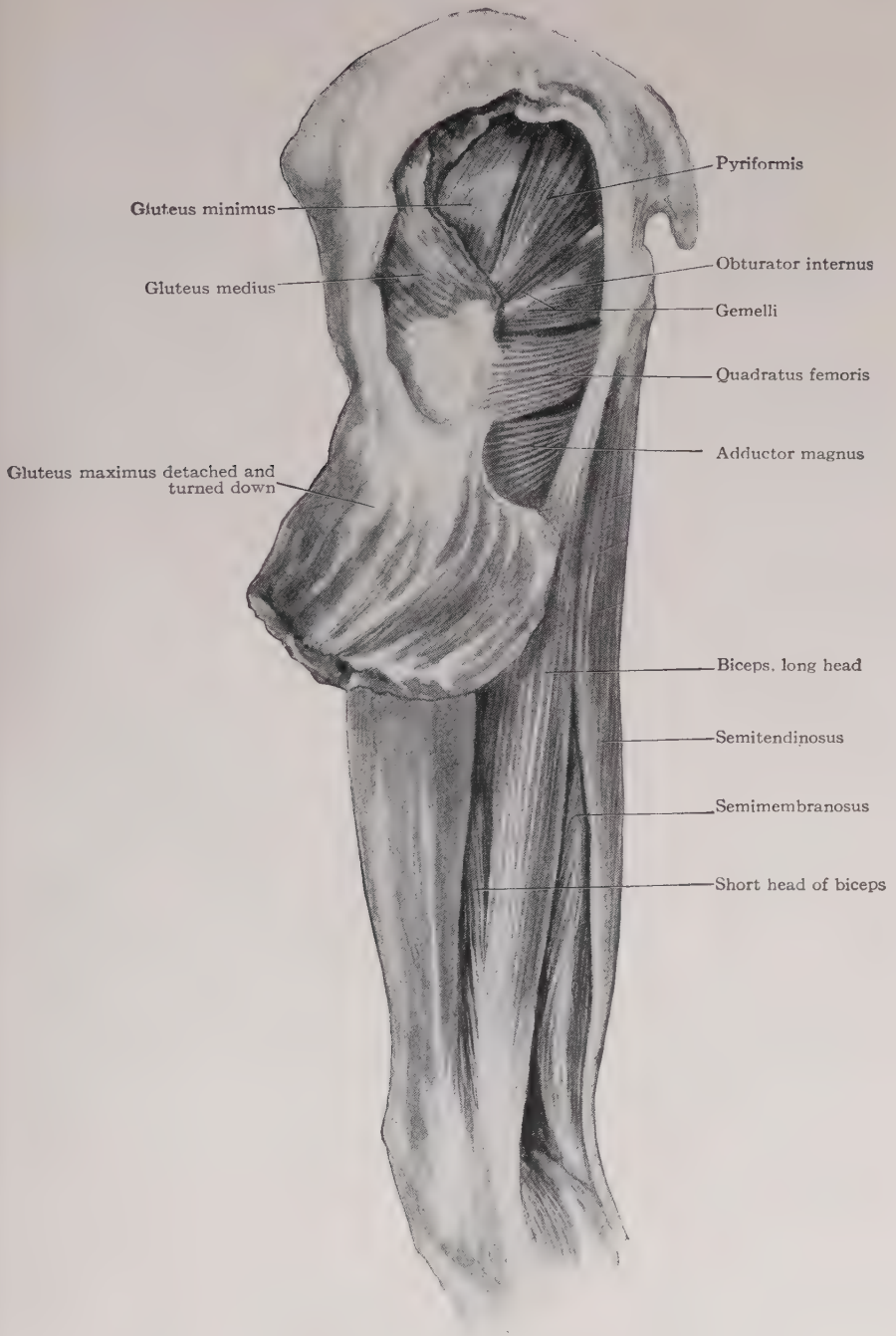


FIG. 561.—View of muscles at the back of the hip. (Davis: Applied Anatomy.)

trochanter. Bryant's triangle is formed by a perpendicular dropped from the anterior superior spine when the patient is lying on the back. The base is the line extending from the tip of the trochanter to this perpendicular, while the hypothenuse is represented by the line joining the trochanter and the anterior superior spine. In fracture of the neck of the femur, the greater trochanter ascends so that it lies above Nélaton's line, and the base of Bryant's triangle is shortened, whereas in fracture of the shaft of the

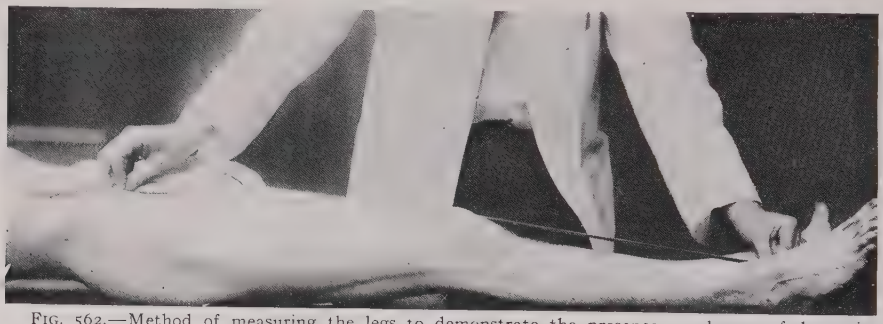


FIG. 562.—Method of measuring the legs to demonstrate the presence or absence of shortening. It is necessary to see that the limbs are placed symmetrically and that the anterior superior iliac spines of the pelvis lie in a transverse plane, forming a right angle with the long axis of the body. The measurements are made from the spine to the internal malleolus.

femur, the normal relations are retained despite the presence of well-marked shortening of the leg.

OPTIMUM FUNCTIONAL POSITION

The position of abduction is the one from which the quickest functional recovery may be expected, following long fixation of the hip. The abductor muscles are few and in walking they serve an important function in holding the pelvis level while weight is borne on the leg. If they are stretched by prolonged immobilization in the neutral or slightly adducted position, a longer time is required for their recovery than when

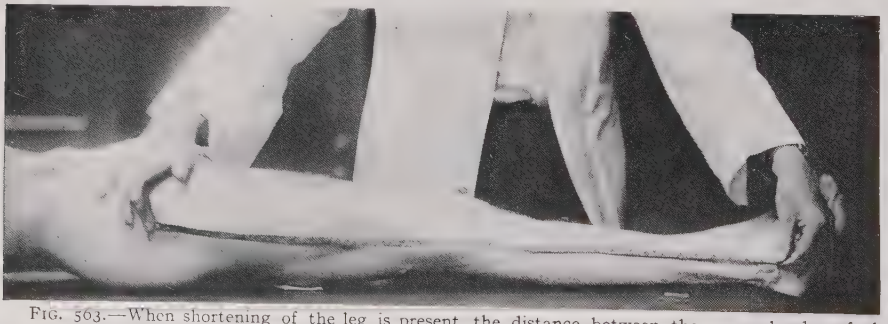


FIG. 563.—When shortening of the leg is present, the distance between the upper border of the greater trochanter and the external malleolus should be measured on both sides to determine whether the part affected lies below or above the trochanter.

they have been relaxed by the position of abduction. Abduction should be combined with slight flexion of the hip and the neutral position as regards rotation, that is, the foot should point directly forward.

When ankylosis is expected, the optimum position is with the hip abducted 10 to 15 degrees, and externally rotated about 5 degrees. The amount of flexion desirable varies, depending upon the sex and the occupation. When an easy sitting position is desired, the flexion should be 45 degrees, but when walking is more important than sitting, the flexion should be about 25 degrees. Surprisingly little disability results from ankylosis of the hip provided that the position is one without deformity. Walking is accomplished without fatigue, and the limp is almost imperceptible.

I. DISLOCATION OF THE HIP

Etiology.— Dislocation of the hip is an uncommon accident and forms only about 2 per cent. of all dislocations. A considerable degree of violence

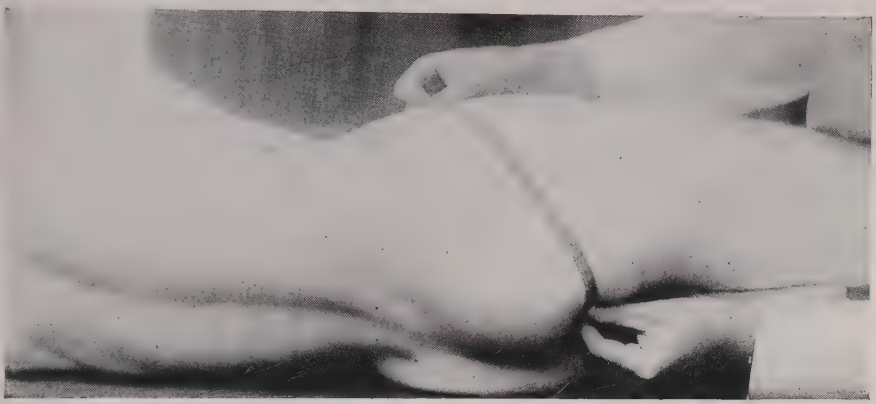


FIG. 564.—Nélaton's line from the anterior iliac spine to the tuberosity of the ischium. Normally, this line passes through the tip of the greater trochanter.

is required for its production, and because the exposure to trauma is greater, it occurs more frequently in males than in females and usually between the ages of fifteen and fifty years.

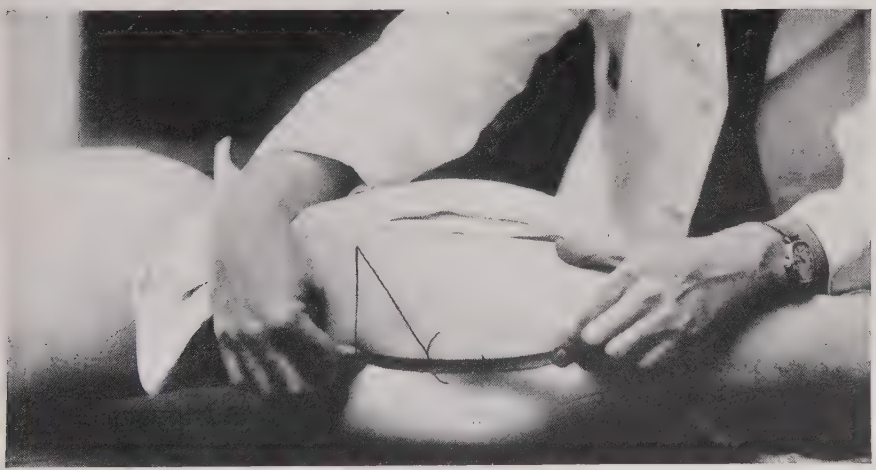


FIG. 565.—Bryant's triangle. With the patient recumbent, a perpendicular is dropped from the anterior iliac spine. The base of the triangle is formed by a line running at a right angle from this to the tip of the greater trochanter. The third side of the triangle connects the trochanter and the anterior iliac spine. In fracture of the neck of the femur or in conditions causing alteration in the angle or length of the neck, the base of this triangle is shortened.

All dislocations of the hip are either anterior or posterior in type. This is easy to understand when it is remembered that the acetabulum lies on the summit of the ridge formed by the junction of the anterior and posterior planes of the pelvis and that these slope away sharply or

either side. When the head of the femur leaves the acetabulum, it, therefore, tends to seek a position of equilibrium in the anterior or posterior direction.

Mechanism.—Dislocation of the hip results almost always from the action of indirect violence or leverage. Bigelow was the first to call attention to the important rôle played by the iliofemoral or "Y" ligament in the mechanism of dislocation and to the possibility of utilizing it as a fulcrum for securing reduction. Owing to its great strength, it is practically never torn, and by its action in limiting displacement it gives rise to the characteristic attitudes of deformity by which the various types of dislocation are recognized.

Anterior Dislocation.— The anterior type of dislocation is usually produced by violent hyperabduction of the hip. The neck and greater trochan-

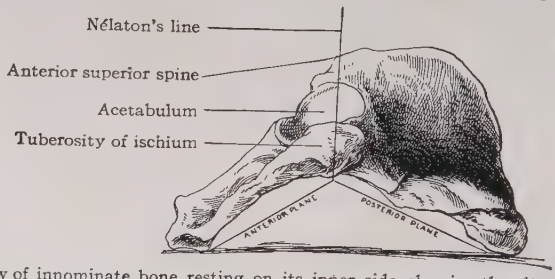


FIG. 566.—View of innominate bone resting on its inner side, showing the situation of the acetabulum at the summit of a ridge, the latter extending from the tuberosity of the ischium to the anterior iliac spine. (Davis: Applied Anatomy.)

ter are forced against the outer rim of the acetabulum, a fulcrum being thus provided, and the head is pried out through a rent in the anterior and inner portion of the capsule. Primarily the head lies in the low position at the thyroid foramen, but, if the thigh is rotated outward, it rises to the high or pubic position. If, on the other hand, the thigh is rotated inward by a continuance of the original force, the low anterior dislocation may be converted into a posterior one.

Posterior Dislocation.— The posterior dislocation is the result of force applied to the leg when the hip is in the position of flexion, adduction, and internal rotation. Leverage is again brought into play, but this time in a different manner. Internal rotation of the thigh tightens the "Y" ligament and winds it around the neck of the femur. The ligament thus becomes the fulcrum, and as the movement continues, the head is forced out through the lower part of the capsule posteriorly. Primarily it lies in the sciatic notch or the low position, but, if the movement continues, it may lodge in the high position on the dorsum of the ilium. A common accident by which this mechanism is produced is an automoble collision in which the passenger is thrown forward from his seat, the thigh being

flexed and adducted and the knee striking the back of the forward seat with an inward twist.

Pathology.—Dislocation of the hip is always accompanied by considerable injury to the structures surrounding the joint. The capsule is torn,

FIG. 567.—Roentgenogram of anterior luxation of the hip. The externally rotated position of the limb is evident from the prominence of the lesser trochanter.

but it has been shown by Allis [1] that the rent in the capsule is always of sufficient size to permit the passage of the head in reduction. The adductor muscles and the obturator externus are usually lacerated in the anterior luxation, while in the posterior type the short external rotators and particularly the obturator internus muscle are liable to injury. The tendon of the latter may become interposed between the neck and the

[1] O. H. Allis, *Samuel D. Gross Prize Essay*—80, Philadelphia, 1896.

acetabulum and interfere with reduction ("dislocation below the tendon"—Bigelow).

The sciatic nerve, on account of its close relation to the head, may be injured in dorsal luxations. It has twice been found at autopsy completely torn across. It may be hooked up over the neck when attempting reduction, and this is particularly likely to happen when converting a

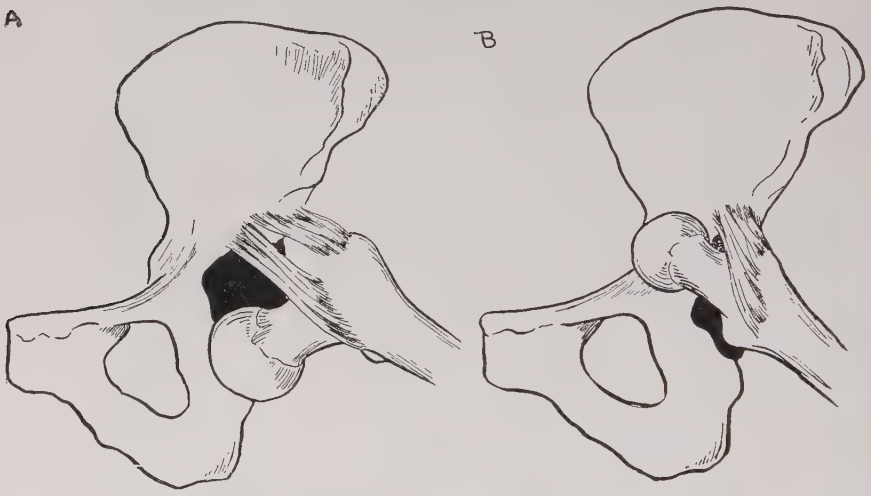


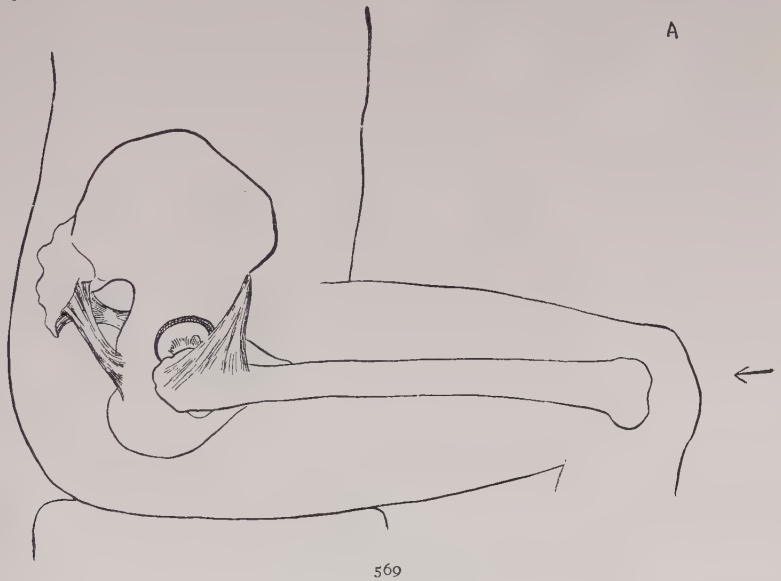
FIG. 568.—Mechanism of anterior dislocation of the hip. (A) Hyperabduction of the thigh causes the trochanter to impinge against the edge of the acetabulum, a fulcrum being thus provided by means of which the head of the femur is pried downward and forward out of its socket. (B) The head at first rests close to the edge of the acetabulum, but on account of the inclination of the anterior plane of the pelvis this position is unstable and it tends to displace either upward and inward or downward and inward.

dorsal into an anterior position. Wide movements of circumduction are especially to be avoided.

Diagnosis.— It is helpful when examining a case of dislocation of the hip or when discussing the symptoms which it presents to visualize the position of the head and greater trochanter from their anatomic relation to the condyles of the femur. For practical purposes the head may be conceived as lying vertically above the internal condyle and the greater trochanter as above the external condyle.

Anterior Dislocation.—Anterior dislocation is characterized by abduction and external rotation of the leg, the knee being flexed. If the head lies in the thyroid foramen, the external rotation and eversion of the foot are less marked, while the abduction is increased. If the head lies in the high or pubic position, there is less abduction but more external rotation. In both cases there is moderate flexion of the hip as well. It is impossible to extend or adduct the limb. There is absence of shortening, and in the thyroid position there is even slight lengthening, but it is difficult to make accurate comparative measurements, and they are, there-

fore, of little value. In the high position the head can be felt in front of the pubis, but in the thyroid type it is difficult to locate. The greater



569

570

FIGS. 569 and 570.—Mechanism of posterior dislocation of the hip. (569) Posterior dislocation may result from the application of force to the leg in the axis of the femur when the hip is in the position of flexion, adduction and internal rotation. Such a mechanism may be brought into play by an automobile collision in which the seated passenger is thrown forward against a solid object. (570) Primarily the hip lies in the sciatic notch or in the low position, but if the movement continues, it may lodge in the high position on the dorsum of the ilium.

trochanter is absent from its usual position, being displaced inward, and a depression remains instead. Occasionally there is pain and numbness in the distribution of the femoral nerve.

Posterior Dislocation.—Posterior dislocation, on the other hand, is characterized by adduction and internal rotation of the thigh, combined with moderate flexion of the hip. With the patient recumbent, the knee is directed inward and forward, the foot is inverted, and the heel often rests on the dorsum of the opposite foot. Flexion of the hip is usually

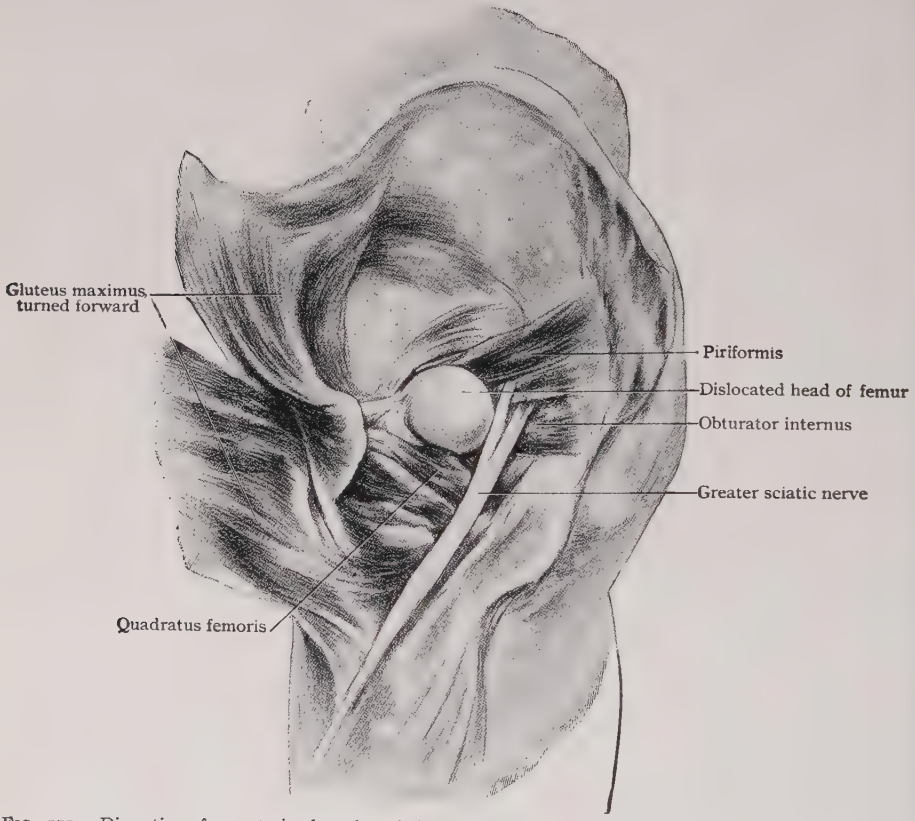


FIG. 571.—Dissection of a posterior luxation of the left femur toward the dorsum of the ilium (below the tendon). (Piersol: Human Anatomy.)

more marked when the head is in the low rather than in the high position. Passive movements are possible to a certain extent, but abduction and external rotation are prevented, while active movements are completely abolished. The head of the femur can be felt indistinctly in its posterior position through the gluteal muscles, while the trochanter lies anteriorly and above Nélaton's line. There is shortening, which can be recognized when both knees are flexed. Dislocation into the vicinity of the great sciatic notch ("dislocation below the tendon") presents the same general features as dislocation onto the dorsum of the ilium, but the deformity is not so marked. In stout subjects it may be overlooked.

Dislocation of the hip presents such a typical clinical picture that there is practically no other condition with which it can be confused. However, a roentgenogram should always be made, partly in order to verify the position, but chiefly for the purpose of demonstrating the presence or absence of an associated fracture of the articular surfaces.

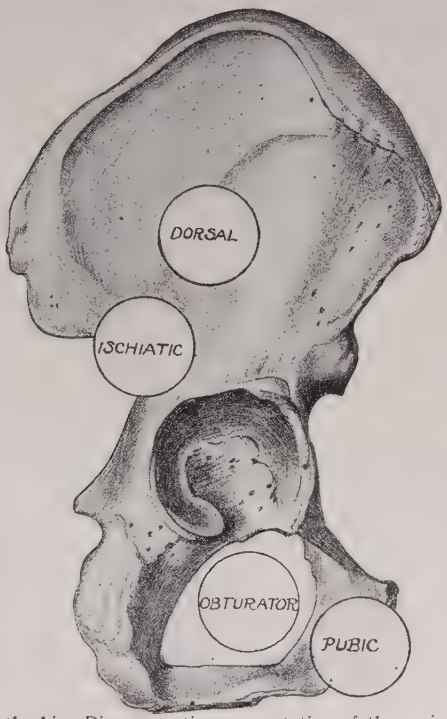


FIG. 572.—Dislocation of the hip. Diagrammatic representation of the various positions which may be assumed by the head of the femur.

Treatment.—Immediate reduction is indicated in all cases and the earlier this is attempted the less the difficulty of replacement. It must necessarily be postponed when the patient is in a state of shock from other associated injuries.

A general anæsthetic is always necessary in order to secure complete muscular relaxation. The patient should be placed on folded blankets on the floor in order to obtain a firm support and to permit the surgeon to work above him in a position to perform the necessary manipulation and utilize his strength to the best advantage. An assistant fixes the pelvis with his hands in order that the force may be applied directly to the hip-joint.

Reduction.—Several methods of reduction are available. Bigelow [2]

[2] H. J. Bigelow, *Dislocations and Fractures of the Hip*, Little, Brown & Co., Boston, 1900.

was the first to originate a method of indirect or leverage replacement. Prior to his time the treatment was by direct manual traction, and when this was unsuccessful, a block and tackle were connected to the leg and tremendous force applied. The results were often very bad. He recog-

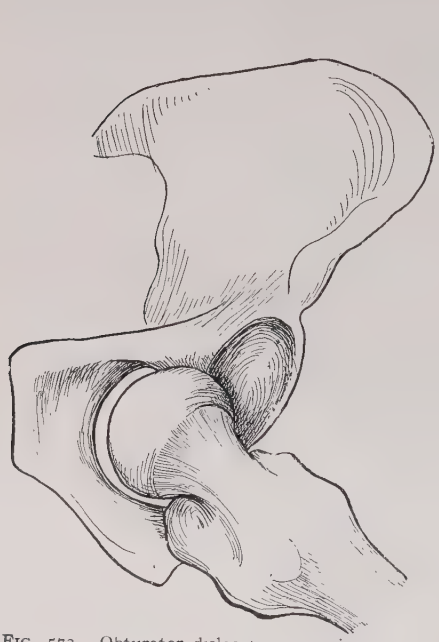


FIG. 573.—Obturator dislocation, showing position of the head of the femur.

FIG. 574.—Obturator dislocation, showing position of the limb.

nized the importance of the "Y" ligament and the possibility of utilizing it to obtain replacement. His methods have since been modified, but only in the direction of simplification.

All methods begin with flexion of the hip. This converts high into low dislocations, brings the head down to the acetabulum, and relaxes the "Y" ligament. The knee is likewise always flexed for greater ease in the control of the manipulation and the more efficient application of traction. In this position the "Y" ligament is then put under tension to provide a fulcrum and by leverage and traction the head is replaced.

1. BIGELOW'S METHOD

a. Anterior Dislocation

Flex the limb toward the perpendicular and abduct it a little to disengage the head of the bone, then lift upward, rotate the shaft strongly inward, adducting it, and then extending the leg.

In simpler terms, the leg should be flexed and abducted, then while exerting traction in the axis of the limb, circumduct inward, that is, move the knee in a circular direction inward and extend the leg (Figs. 581, 582).

b. Posterior Dislocation

With the knee bent and the hip flexed adduct and internally rotate to disengage the head from behind the socket. "If the bone can now be abducted beyond the perpendicular, the capsule and other tissues are probably so torn or relaxed that reduction may be accomplished without much difficulty; the thigh need only be forcibly lifted or jerked toward the ceiling with a little simultaneous circumduction or rotation outward to direct the head of the bone toward the socket." (Bigelow.)

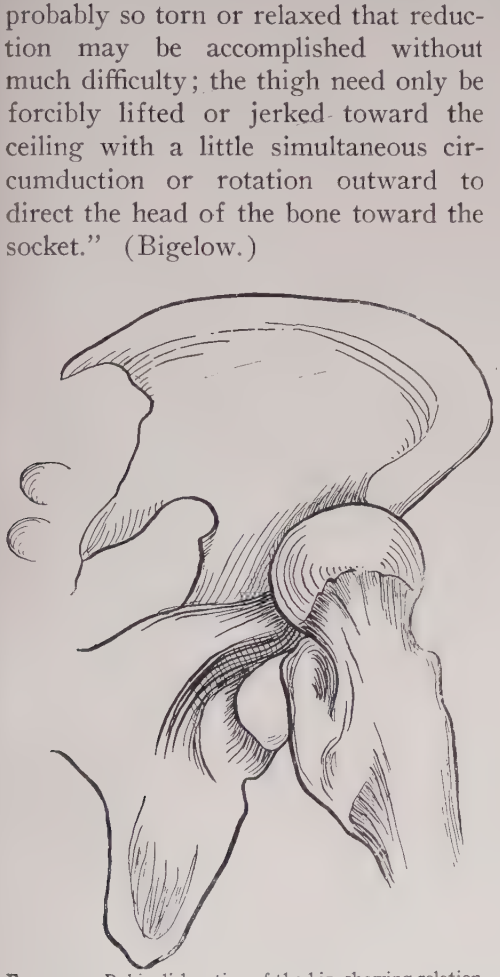


FIG. 575.—Pubic dislocation of the hip, showing relation of the head of the femur to the pubic bone.

FIG. 576.—Position of the limb in pubic dislocation.

The essential is to exert strong traction in the axis of the thigh, while the hip is flexed, adducted, and internally rotated. If reduction does not occur, circumduct outward while maintaining the traction; that is, abduct, externally rotate, and then extend (Figs. 584, 585).

2. ALLIS'S METHOD

The essence of this method is to make the head of the bone retrace the path by which it left the socket, only in the reverse direction.

a. Anterior Dislocation

Flex the thigh and abduct. Make traction on the limb in this position. This brings the head near its point of exit from the capsule. An assistant now places his hands on the head and pushes strongly outward while the operator abducts. The hands of the assistant thus become a fulcrum, and adduction of the thigh forces the head into the socket. The leg is then extended (Fig. 583).

b. Posterior Dislocation

Flex the hip on the abdomen to bring the head into relation with the opening in the capsule and lift strongly on the bent knee. If reduction does not occur, rotate inward and lift. If obstruction still exists, rotate outward, exert traction and then extend. Replacement may be considerably aided by the upward pressure of the assistant's thumbs upon the head (Fig. 586).

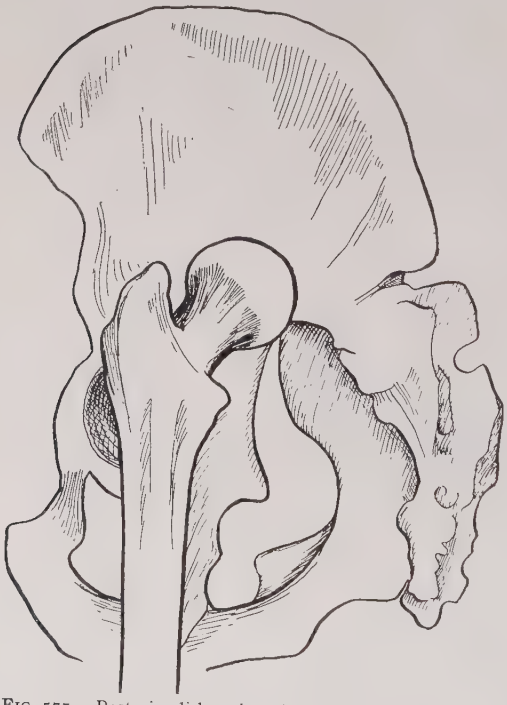


FIG. 577.—Posterior dislocation, showing position assumed by the head of the bone.

FIG. 578.—Position assumed by the limb in the posterior type of dislocation.

3. STIMSON'S METHOD

The aim of this method is to utilize the weight of the patient's leg as a traction force to overcome the resistance of the muscles and effect

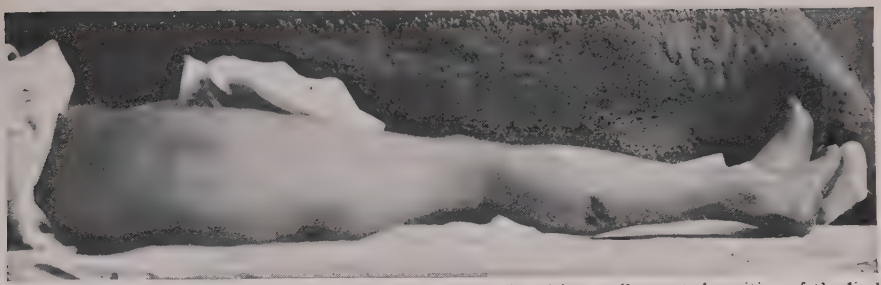


FIG. 579.—Dorsal dislocation of the hip. Note the adducted and internally rotated position of the limb. (Fracture Service, M. G. H.)

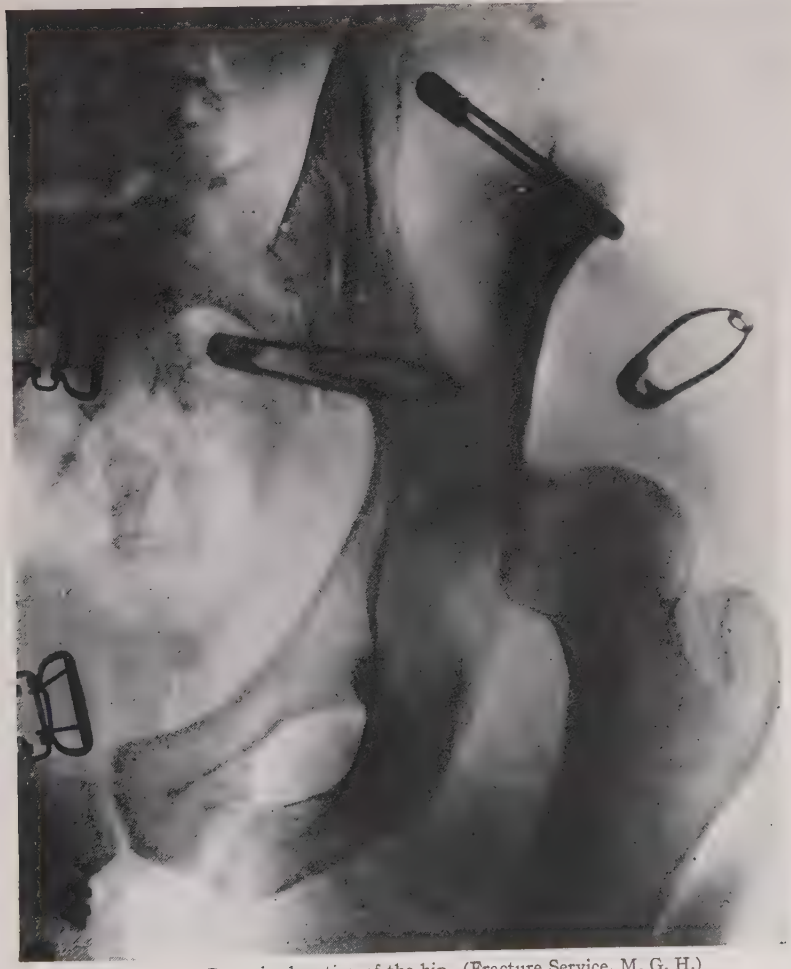
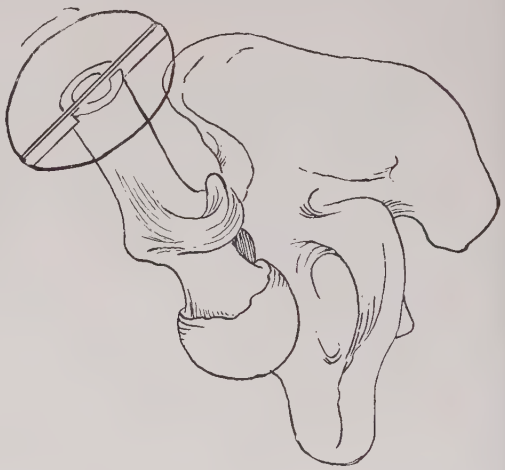


FIG. 580.—Posterior luxation of the hip. (Fracture Service, M. G. H.)

reduction. Manipulative violence is avoided and in a large percentage of cases with the dorsal type of luxation, replacement may be obtained without anæsthesia other than a full dose of morphine. For this reason, it is a very useful method in the case of old enfeebled patients, or when the dislocation is associated with a condition of shock.

The patient is placed face downward on a table with the hips projecting beyond the edge. An assistant holds the uninjured leg in the extended position. The affected limb is allowed to hang downward in the flexed position, while the knee is bent and the foot held by the sur-

581



582

FIGS. 581 and 582.—(581) Bigelow's method of reducing an anterior dislocation of the hip by traction and circumduction. (582) Drawing to illustrate the mechanism employed. The "Y" ligament is made tight and serves as the fulcrum.

geon. The weight of the leg alone, aided by gentle movements of rotation, will, after a short period, effect replacement in most cases. Reduction may be aided by placing a sand bag on the leg close to the knee to increase the traction force, or the surgeon may press downward upon the leg with the hands (Fig. 587).

After-treatment.— Following reduction very little care is required. The chief aim should be to avoid over-treatment. There is very little tendency to redisplacement unless there is present a complicating fracture of the acetabulum.

The legs should be bandaged together to prevent too free abduction, or moderate traction may be applied with pulley and weight. The hip should be covered with a soft, elastic bandage to reduce the swelling.

Slight active movements should be allowed at the end of three to seven days, depending upon the severity of the lesion. Massage is usually unnecessary. At the end of a week the restraining dressing should be removed, and the patient encouraged to move the hip more freely. At

the end of two to three weeks active weight-bearing may be permitted, and usually full function is restored by the end of four to five weeks.

Old Unreduced Dislocations.—The difficulty of obtaining reduction by the closed method rapidly increases with the passage of time, but success-

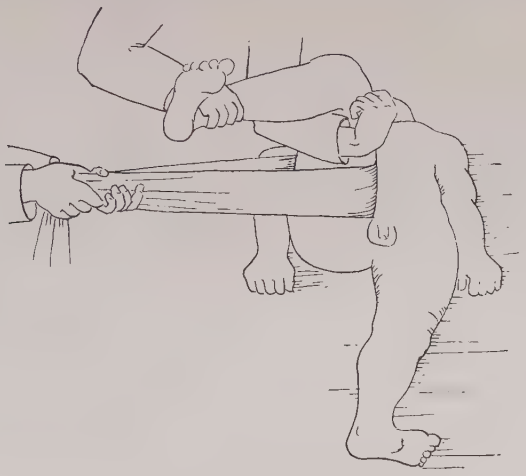
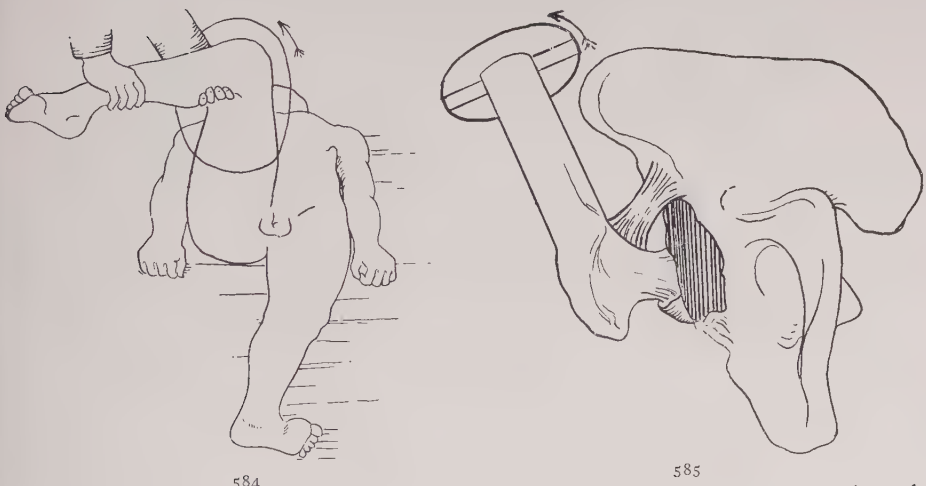


FIG. 583.—Allis's method of reducing anterior dislocation of the hip.



584 585

FIGS. 584 and 585.—(584) Bigelow's method of reducing a posterior dislocation of the hip by traction and circumduction. (585) Drawing showing the position of the bones during manipulation.

ful results should be obtained up to the end of six weeks. After that time the results are uncertain, although recently two cases have been reported in which replacement was successfully accomplished after six months. The chances of successful manipulative reduction in these old cases are greatly increased by a preliminary course of heavy traction

with ice tong calipers for a period of four weeks. After six months, open operative reduction would seem the method of choice.

Operative Reduction.—The Smith-Petersen incision provides an excellent exposure of the acetabulum. The capsule must be incised freely and the acetabulum cleared, following which, by movements of flexion and rotation, the head may be freed and brought into view. After reduction and closure, the hip should be abducted and fixed by the application of a plaster of Paris spica. Immobilization should be maintained for four to six weeks, when active movements and massage may be inaugurated. The operation carries a considerable risk and should be attempted only by a surgeon of experience. The prognosis for a freely movable hip is uncertain, but even in the absence of motion, the patient may be assured of a painless, stable leg, with absence of deformity.

FIG. 586.—Allis's method of reducing a posterior dislocation of hip.

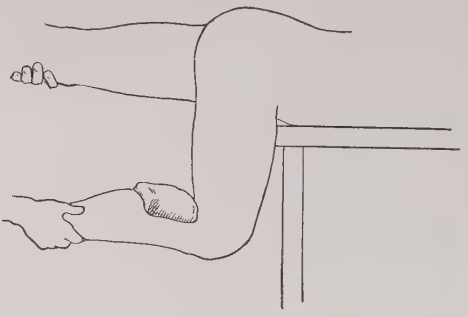


FIG. 587.—Stimson's method of reducing dislocated hip.

Habitual Recurrent Dislocation.—A few cases of this condition have been reported, but they are surgical curiosities, and practically a recurrence of a dislocation of the hip after the expiration of four weeks need not be considered if proper after-treatment is employed.

Fracture Dislocation.—Dislocation of the hip may be accompanied by a fracture of the rim of the acetabulum or of the articular surface of the upper end of the femur. The diagnosis of this complication can be made only from the roentgenogram. When present, the fragment may become interposed between the head and the acetabulum in such a way as to hinder reduction, or if it involves the rim of the acetabulum, it may allow the head to redislocate after reduction. In the former condition, repeated gentle efforts at reduction will usually dislodge the fragment. In the latter case, recurrence of the dislocation may be prevented by the application of constant traction to the leg with a weight and pulley.

The presence of an associated fracture considerably affects the prognosis in a case of dislocation, and necessitates a longer period of treatment. Immobilization should be maintained for four to six weeks, and weight-bearing not permitted until still later. In rare cases it may be necessary to remove the fragment or to replace and fix it by operation.

Pathological Dislocation.—Spontaneous dislocation of the hip, always dorsal in type, occurs not infrequently as a complication in many acute diseases of a protracted type, such as typhoid fever, pyemia, endocarditis,

FIG. 588.—Specimen illustrating fracture dislocation of the acetabulum. (Warren Anatomical Museum.)

etc., when there is general wasting of muscles and the patient is allowed to remain for a long time with the thigh flexed and adducted. It also occurs quite commonly as the result of a local process affecting the hip-joint with destruction of the head and neck of the femur, such as tuberculosis, osteomyelitis, etc.

Prevention is always the best treatment. In the first class of cases good nursing care is required, with frequent change in the position of the limbs and the avoidance of postures which conduce to dislocation. In the second type luxation may be prevented by fixation in the abducted position or by the use of traction.

In the former group reduction by the open method may be attempted when the restoration of the patient's general health permits it. In the latter group the best result will probably be obtained by ankylosis with the hip in the position of optimum function.

II. FRACTURE OF THE ACETABULUM WITH INTRAPELVIC DISPLACEMENT OF THE HEAD OF THE FEMUR

Causation.— This injury usually occurs as the result of force applied directly to the greater trochanter and acting in the direction of the neck of

FIG. 589.—Roentgenogram of intrapelvic dislocation of the head of the femur showing the entire acetabulum displaced inward. (Fracture Service, M. G. H.)

the femur. A frequent cause is a fall on the hip. The femoral head is driven against the acetabulum, fracturing it, and with sufficient force to drive the head through into the pelvis.

Formerly this injury was considered rare, but with the modern routine roentgen examination it has been shown to be not uncommon. It is inter-

esting to note that fractures of the acetabulum, neck of the femur, or greater trochanter, may all result from the same type of violence. The factor that determines the type of lesion in each particular case seems to be the individual's point of least resistance. In old age the femoral

FIG. 590.—Fracture of the acetabulum with intrapelvic displacement of the head of the femur.

neck yields more readily, and this applies also in childhood. In middle age the neck bears the strain better, and in that case the acetabulum gives way. The injury is rare in children, and is more common in women than in men.

Pathology.— The acetabulum may be fractured without any displacement of the head. Such cases are difficult to diagnose even with the aid

of a roentgenogram. In other cases the fracture lines may lie entirely outside the acetabulum, but in close relation to it, and the acetabulum may be displaced upward and inward with the femoral head (Fig. 589). More commonly there is a radiating fracture of the acetabulum with depression

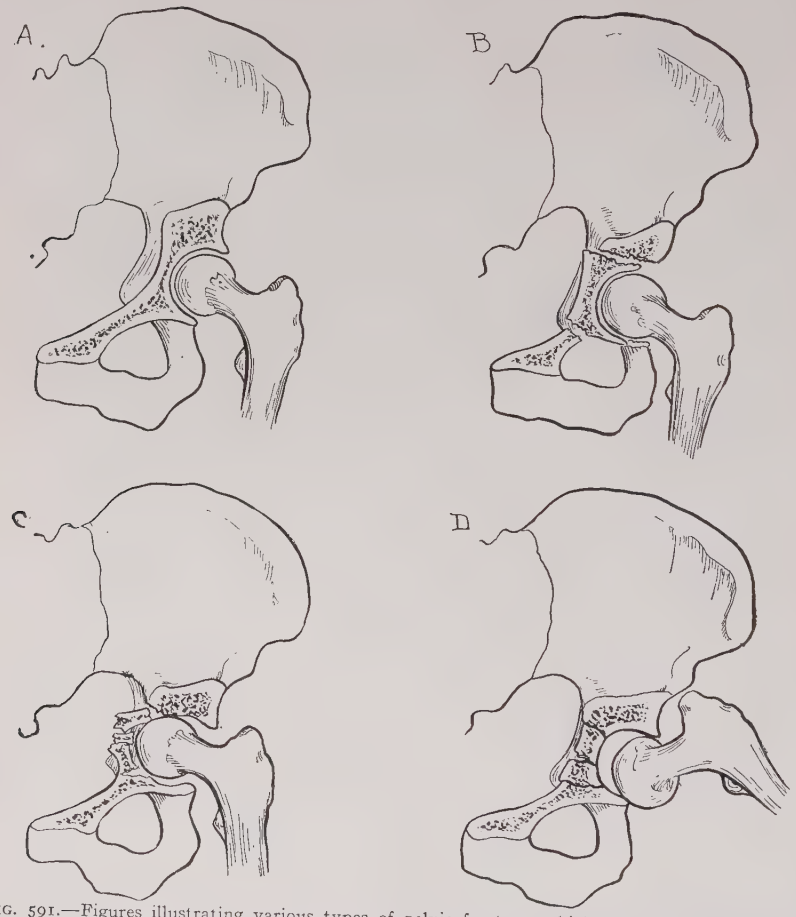


FIG. 591.—Figures illustrating various types of pelvic fracture, which may accompany intrapelvic dislocation of the head of the femur. (A) Normal hip. (B) Fracture about the margin of the acetabulum with middle fragment displaced inward. (C) Common type of fracture and displacement. (D) Reduction by manipulating the hip into the position of complete abduction.

of the fragments and deepening of the socket. If the violence has been severe, the head lies inside the pelvis, covered by the fibres of the iliopsoas muscle, and the acetabular fragments may be locked about the femoral neck, imprisoning the head. There is accompanying hæmorrhage and swelling, but rarely is there rupture of the peritoneum or damage to the viscera.

If reduction is not accomplished early, fibrous union quickly occurs, and after two weeks it may be impossible to correct the deformity. The

end result, if unreduced, is always limitation of motion, particularly abduction and internal and external rotation.

Diagnosis.— The diagnosis is made from the history of the type of injury, the limitation of motion, especially internal rotation, demonstra-

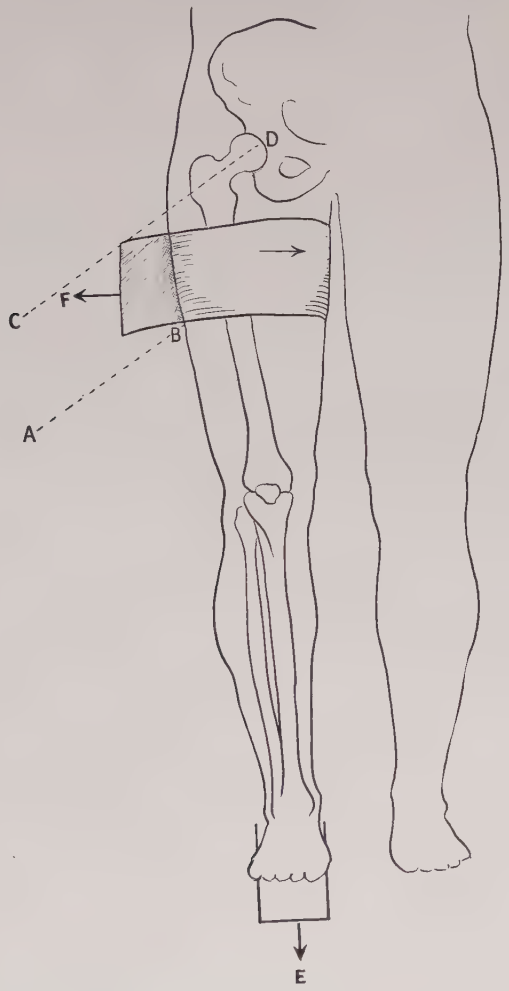


FIG. 592.—The Maxwell Ruth method of combined lateral and longitudinal traction as used in fractures of the hip. Drawing to illustrate the mechanics of the method. E represents the longitudinal extension pulling in the axis of the limb. F represents the lateral traction band applied in a manner to internally rotate the limb and exert a lateral pull. The combined action of the two forces may be represented by their resultant A B, which corresponds in direction with C D, the axis of the neck of the femur.

tion of slight shortening (1 to 3 cm.), and the ascent of the greater trochanter with reference to Nélaton's line and Bryant's triangle. The distance between the symphysis pubis and greater trochanter is also usually diminished and the latter appears depressed.

The condition must be differentiated from fracture of the neck of the femur and dislocation of the hip. This is not difficult in cases with marked displacement of the head of the femur, as the tender rounded swelling inside the pelvis may be demonstrated by rectal examination or more rarely by deep palpation of the abdomen just above Poupart's ligament. In dislocation of the hip the attitude is characteristic and the dislocated head may be felt lying anterior or posterior to the acetabulum. In fracture of the femoral neck there is usually external rotation of the leg, and except in the case of an impacted fracture, rotation is not limited.

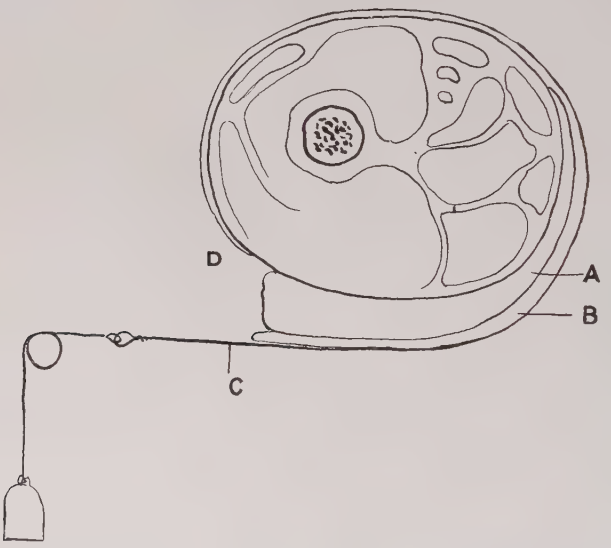


FIG. 593.—The Maxwell Ruth method of combined lateral and longitudinal traction as used in fractures of the hip. Drawing to illustrate the method of arranging the lateral traction band. A, felt pad. B, protective strip of cardboard. C, adhesive traction strip which is applied to the thigh, beginning on the outer side at D and carried around the inner side.

In the cases with only slight displacement, however, the diagnosis must, in the last analysis, chiefly depend upon the roentgenogram.

Reduction.—Reduction should always be attempted in recent cases with deformity. Under general anæsthesia, with muscle spasm abolished, the various movements which the hip permits should be tested, and the attempt made by the use of gentle force to manipulate the leg into the position of complete abduction. The greater trochanter is thus made to impinge against the rim of the acetabulum and provide a fulcrum. Further abduction then serves to pry the head back and out of the pelvis. Care is necessary, as, if the head is solidly held in its displaced position, the use of too much force is likely to result in a fracture of the neck of the femur.

When much resistance to abduction or rotation is encountered, or when the roentgenogram shows well-marked displacement, the best procedure is to pass a folded sheet around the inside of the thigh close to

the groin, by means of which an assistant exerts lateral traction upon the upper end of the femur. This provides a fulcrum, and leverage may be exerted upon the head in a direction to correct the deformity by strong adduction of the leg. When reduction is obtained, the traction should be continued until the leg has been swung out into full abduction, in which position the correction is maintained by the impingement of the neck and trochanter against the rim of the acetabulum.

Fixation.— The position of abduction is of value not only because it prevents recurrence of the deformity, but also because it permits healing

FIG. 594.—Maxwell Ruth method of combined extension, showing arrangement of lateral traction strip.

of the fracture in the absence of pressure from the opposed articular surface and retains a movement which experience shows is most likely to be lost. Therefore, following reduction, the hip should be immobilized in the position of complete abduction by the application of a plaster of Paris spica, extending from the ankle to well above the rib margin.

After-care.— Immobilization should be maintained for six to eight weeks. At the end of this period the plaster should be removed and mobilization of the hip by baking, massage, and active exercises begun. Light weight-bearing with crutches is permitted two weeks later, and at the end of ten to twelve weeks full weight-bearing should be encouraged.

The Traction Method.— In cases with marked displacement, reduction may prove unsuccessful. Such cases may be treated by the application

to the leg of combined longitudinal and lateral traction. With the patient recumbent in the dorsal position, adhesive traction bands are applied to the leg extending from the ankle to the hip, in the ordinary manner. The

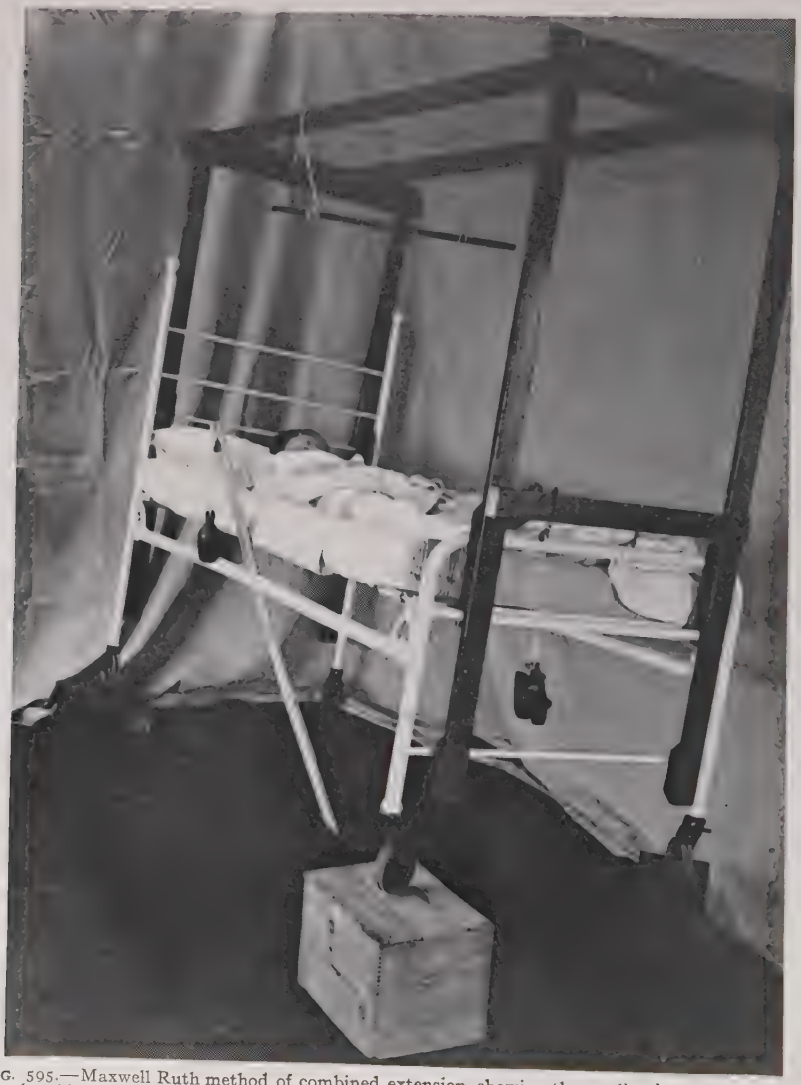


FIG. 595.—Maxwell Ruth method of combined extension, showing the application of traction in both the lateral and longitudinal directions; also the method of elevating the bed in order to utilize the weight of the body for counter-traction.

bands are fastened below the foot to a spreader which prevents pressure on the ankle, and this in turn is connected to a weight by means of a cord running over a pulley at the foot of the bed. Lateral traction is provided by a broad adhesive strip encircling the middle of the thigh with

the ends fastened to cords, which in turn are led over a pulley fastened to the side of the bed and attached to a weight.

As pointed out by Maxwell and Ruth,[3] the resultant of these two forces acting at a right angle to each other, if the weights be equal, is a single force which acts in a direction bisecting the angle and which approximates more or less the axis of the neck of the femur (Fig. 592). Variation in the line of pull may be obtained by increasing one or other of the two weights. By this method a considerable degree of correction may be obtained and ultimately good function. The traction should be continued for six to eight weeks and weight-bearing with crutches begun at the end of ten weeks.

Open Reduction.—Operative reduction of the unreduced cases is not advisable. The operation itself is severe, and the possibility of correction of the deformity slight even when the field is exposed. Conservative treatment is likely to give far better results even when reduction is not obtained.

Prognosis.—Surprisingly good function may be obtained in the majority of these cases even though considerable deformity remains, as shown by the roentgenogram. Later, difficulty may arise from the development of a traumatic arthritis due to an element of strain in the use of the joint. When this process is severe, it may be necessary to perform an ankylosing operation upon the hip to relieve the accompanying pain and disability.

III. SEPARATION OF THE CAPITAL EPIPHYSIS OF THE FEMUR

Etiology.—The upper epiphysis of the femur usually unites with the shaft from about the seventeenth to twentieth years. In childhood the epiphysis is largely cartilaginous and resists strain better than the weaker neck, and fracture of the latter is, therefore, the more common lesion. In certain youths at about the age of puberty, however, usually following only slight violence, a considerable displacement of the epiphysis may occur. Complete separation is rare, and the common lesion is merely a slipping or partial displacement downward and is often accompanied by so little disability as to result in the patient not consulting a physician until some months after the original injury when the acute symptoms have all subsided and persistent limp is the only complaint.

"Adolescent Rickets."—The condition probably has its origin in some underlying constitutional disturbance, which weakens the epiphyseal junction. Although the exact nature of this disturbance is unknown, it falls within the general designation of "Adolescent rickets," but is probably not allied to true rickets. The cases in which slipping of the epiphy-

[3] C. E. Ruth, *Journ. Amer. Med. Asso.*, December 3, 1921, p. 1811.

sis occurs fall definitely into two groups. The first is made up of tall, slender, rapidly-growing lads, and one may assume that in them the proliferative process at the epiphyseal line, by which new bone cells are formed, is taking place more rapidly than the accompanying deposition of calcium salts, and that in consequence the epiphyseal junction is weakened. The second group is composed of short, fat boys with pasty color, undeveloped genitals, feminine contour, and retarded adolescence. It is generally assumed that these cases are due to disturbance in function of some of

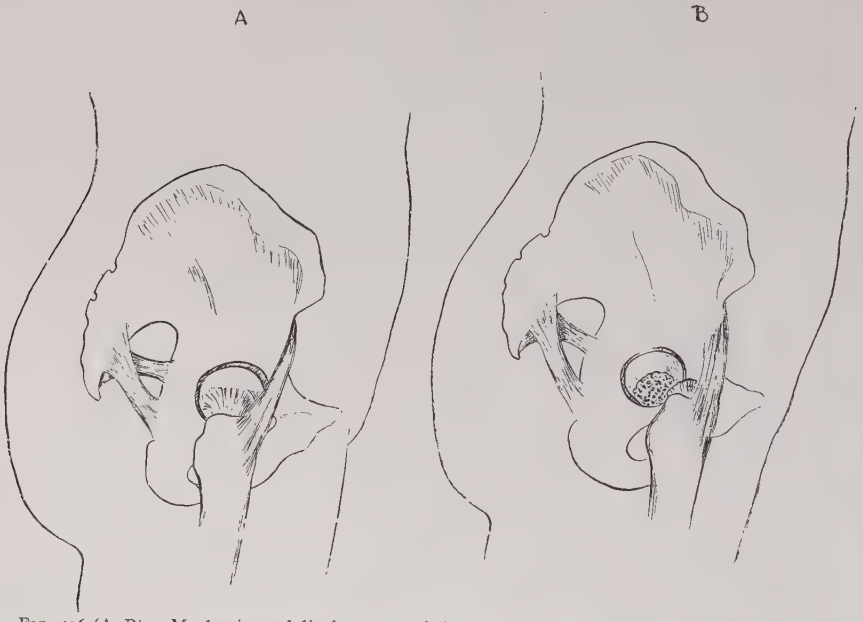


FIG. 596 (A, B).—Mechanism of displacement of the upper femoral epiphysis. (A) Hyperextension of the hip tightens the "Y" ligament and provides a fulcrum by means of which leverage is applied to the neck of the femur. (B) Continuation of the force causes the epiphysis to separate, the neck being displaced forward and the femur externally rotated and adducted.

the glands of internal secretion, but no definite proof of the real pathology has yet been forthcoming. Less frequently, the condition is encountered in girls, usually of a fat, anæmic type.

Mechanism.— The mechanics of the injury is fairly definite. It occurs almost always from stumbling or tripping. The leg is hyperextended, which tightens the "Y" ligament and provides a fulcrum, while the neck becomes the short end of the lever and is partially separated or wrenched from the epiphysis.

Diagnosis.— In the cases with partial separation, there is usually a history of a strain of the hip accompanied by pain on motion for a few days and followed by slight but persistent limp. Examination shows slight shortening of the affected limb with moderate limitation of abduction and internal rotation. External rotation is abnormally

597 598

FIGS. 597 and 598.—Separation of the upper epiphysis of the femur. (597) Before reduction. (598) Following open reduction. (Fracture Service, M. G. H.)

free, while adduction and flexion are normal. The roentgenogram shows the epiphyseal centre displaced downward and backward and an appearance of coxa vara.

In the rare cases with complete separation of the epiphysis, the findings at examination are the same as in fracture of the neck of the femur. There is eversion of the limb, ascent of the greater trochanter, and shortening. These cases can be differentiated from fracture of the neck only by roentgen examination.

Treatment.— Correction of displacement is all-important in these cases, as otherwise the deformity tends to increase, the hip becomes still further adducted and externally rotated, the movements of internal rotation and abduction are abolished, and permanent lameness may be expected. In later years osteo-arthritic changes are apt to develop and tend still further to increase the physical handicap.

Reduction.—In the cases with partial separation or slipping of the epiphysis, the displacement may usually be corrected well enough by manipulative reduction under general anæsthesia. Effort should be directed toward obtaining full abduction of the hip, using the trochanter against the ilium as the fulcrum and the lower lip of the acetabulum as the point to fix the epiphysis. At the same time, the limb should be forced into internal rotation to correct the backward displacement.

Fixation.— Following reduction the hip should be fixed in the position of full abduction, extension, and internal rotation in a long plaster of Paris spica, extending from the toes to above the costal margin. To hold the internal rotation, the knee should be moderately flexed.

Fixation should be maintained for at least two months, and thereafter the hip should be protected from full weight-bearing by the use of a Bradford abduction caliper splint, which takes part of the weight on the tuberosity of the ischium and maintains abduction by a prolongation of the ring which curves over the pubis and around against the opposite ischium (see Fig. 621). The splint should be provided with a lengthening attachment to allow for growth. It should be worn for six to eight months, but during this period active use of the leg should be encouraged.

Open Reduction.—In the cases with complete separation of the epiphysis, reduction by the closed method is frequently unsuccessful, and in these open reduction will be required. The hip is best approached by means of the Smith-Petersen incision, which passes down anteriorly between the tensor fasciæ femoris and sartorius muscles and is prolonged backward along the iliac crest, with subperiosteal reflection of the upper portion of the flap. The capsule is opened and the fragments approximated. Internal fixation is not required, the position being held by abduction and internal rotation of the limb and a long plaster spica as in the case of reduction by the closed method.

IV. FRACTURE OF THE NECK OF THE FEMUR

Etiology.—Fracture of the neck of the femur has always been a subject of exceptional interest because of its common occurrence in elderly persons, its slowness in healing, and the difficulties encountered in its treatment. While primarily an injury of old age, it should not be forgotten that it may occur at any age, even in children. Whitman [4] has seen thirty-six cases of fracture in childhood, and Hesse [5] has reported forty-two others. By far the largest number of cases occur in patients who have passed the age of fifty, and the great majority are women. In a group of 526 cases of fracture of the femur recently reported by Speed,[6] 124, or 24 per cent., were fractures of the neck, while 118, or 22 per cent., were fractures of the base of the neck in the intertrochanteric region. Of these, 96 per cent. occurred in persons beyond the age of 50, and 60 per cent. of the patients were women.

Causation.—In old persons the accident is usually the result of comparatively slight trauma, a misstep, stumble, or fall on the hip. It has been argued by many that the fracture precedes the fall rather than that the fall occasions the fracture, but this has not been established. Several factors are of importance in explaining this extreme vulnerability of the femoral neck to injury. First, the femur is a long bone and the ligaments and muscles of the hip are attached in the trochanteric region in such a way as to provide a fulcrum throwing great leverage force upon the short and unprotected neck. Second, the neck forms an angle with the shaft and this constitutes a point of mechanical weakness which is the more important when its function in transmitting the body weight to the leg is considered. In a fall upon the feet or hip, it is particularly exposed to injury from cross breakage strain. Third, absorptive and rarefactive changes occur in the skeleton in old age, and Humphry has shown that these begin first of all in the neck of the femur. Fourth, in old age the hip is likely to be the seat of an hypertrophic arthritis, and Ely[7] has pointed out that this disease affects the underlying bone as well as the articular surfaces, causing the formation of small cavities. Such a process in the neck of the femur leads to considerable weakening of the bone.

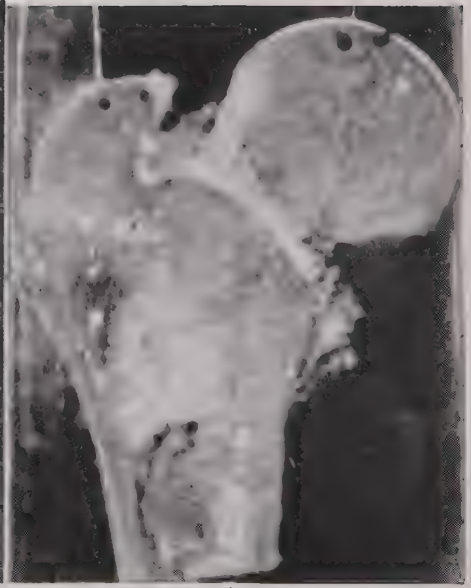
In robust adults the fracture is produced by great violence applied directly to the trochanter and lateral aspect of the thigh and occasionally by a fall from a height upon the feet. In childhood it results mainly from falls with hyperextension of the thigh.

---

[4] Royal Whitman, *Annals of Surgery*, June, 1897.
[5] Hesse, *Beiträge z. path. Anat. und z. allegemeinen Path.*, 1905, 7, Supple.
[6] K. Speed, *Archives of Surg.*, January, 1921, p. 45.
[7] L. W. Ely, *Col. State Journ. of Med.*, October, 1922, p. 329.

599

600



601

FIGS. 599, 600 and 601.—Specimens illustrating various types of fracture of the neck of the femur. (599) Subcapital fracture with absorption of the neck and non-union. (600) Fracture of the neck of the femur with absorption of the neck and non-union. Note that only a small portion of the articular surface of the head remains. (601) Fracture of the neck of the femur with fibrous union. Head in good position. (Warren Anatomical Museum.)

Healing.—From time immemorial it has been recognized that bony union occurs only exceptionally in this type of fracture. Sir Astley Cooper at one time stated that it never did occur, although he later changed this opinion. It has since been recognized that fractures at the base of the neck unite readily, while those closer to the head do so only

FIG. 602.—Specimen illustrating type of fracture of the neck of the femur. Impacted fracture of the base of the neck. There is marked coxa vara and the shaft is externally rotated. (Warren Anatomical Museum.)

with difficulty. Also very commonly the portion of the neck attached to the proximal fragment becomes absorbed, leaving only a small portion of bone, filling the acetabulum and containing the articular surface. From this and other evidence it has been shown that failure of union is chiefly due to three factors:

1.—Insufficient Blood Supply to the Cervical Fragment and Senile Changes in the Bone
2.—Presence of the Synovial Fluid Which Bathes the Fractured Surfaces
3.—Incomplete Approximation of the Fragments

Causes of Non-union.—The main blood supply of the head and neck of the femur is obtained from vessels which enter through the capsule.

A small amount of blood may also be obtained from a vessel running in the ligamentum teres, although this usually disappears some time in adult life. When fracture occurs proximal to the point of capsular attachment, it is, therefore, conceivable that the central fragment may be entirely deprived of blood and that its fate will be that of any bone graft,

FIG. 603.—Specimen illustrating type of fracture of the neck of the femur. Impacted fracture of the base of the neck with solid union. (Warren Anatomical Museum.)

that is, absorption and replacement by ingrowth of blood-vessels and bone cells from the distal fragment.

Numerous dissections and study of specimens have shown, however, that complete separation of the proximal fragment from its capsular connections is exceptional. The posterior portion of the capsule is attached at a much higher level than the anterior portion, and the synovial membrane is reflected upon the neck even more centrally. To be entirely intracapsular the fracture must really be subcapital, and this is rare. In addition, bridges of separated but untorn periosteum and synovia usually persist and connect the capsule with the head. Thus it is seen that while the blood supply may be impaired, it is rarely entirely wanting, and might be entirely adequate were it not for the complication added by the presence of a senile, degenerative process already well established in the bone.

Just how the presence of synovial fluid bathing the fractured surfaces acts to interfere with union is not understood, although the effect itself has long been recognized. Certainly, modern experience with joint fractures elsewhere has tended to lessen the importance attributed to this factor.

Probably the most important single factor in the production of nonunion is failure to approximate the fractured surfaces and immobilize them for a sufficiently long period afterward. That the power of the reparative processes is lessened is evident, but that they are completely wanting has not been shown. Bony union may be expected in all but

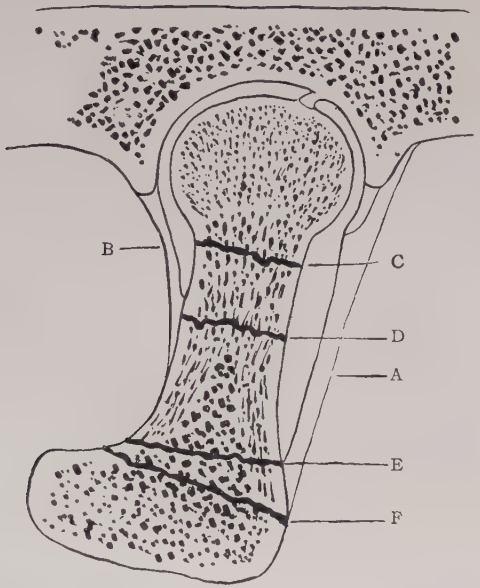


FIG. 604.—Horizontal section through the neck of the femur to show various sites of fractures and their relation to the capsular attachments. (A) Anterior capsule attached near the intertrochanteric line. (B) Posterior capsule attached near the middle of the neck. (C) Subcapital variety of fracture, the situation being entirely intracapsular (rare). (D) The usual situation of fracture of the neck, partly intra- and partly extracapsular. (E) Fracture at the base of the neck but still entering into the joint. (F) Extracapsular fracture. This corresponds to the intertrochanteric line.

the very aged patients with fracture in the proximal portion of the neck, and even in these, strong fibrous union permitting excellent function may be expected, but a closer approximation of the fractured surfaces must be secured than is required in other fractures, and the immobilization must be complete and proportionately longer because of the slowed process of healing.

Types of Fracture.—It has been customary to classify fractures of the neck as intra- or extracapsular with reference to the points of capsular attachment (see Fig. 604). However, greater study of specimens has shown that most fractures are partly intracapsular and partly extracapsular so that this distinction has lost its force. It is more accurate to distinguish them as central or subcapital fractures and fractures through the base of the neck. In addition, fractures of the neck may be complete, incomplete, or impacted. The complete variety occurs more commonly at the proximal portion of the neck, while the impacted or incomplete types are usually situated at the base. True impaction is much rarer than

supposed. Many of the so-called impactions are complete fractures in which gross displacement has been prevented by interlocking of some of the projecting splinters. On the other hand, cases of well-marked impaction may be encountered, and there are instances where the base of the

Fig. 605.—Subcapital variety of fracture. Prognosis bad. (Fracture Service, M. G. H.)

neck has been driven into the trochanteric portion of the shaft so solidly that it has even resisted the strain of active weight-bearing.

Displacement.—In complete fractures of the subcapital variety with separation, the femoral shaft and greater trochanter are displaced upward on the ilium and externally rotated. The first is of course the result of muscular contraction, while the latter is due to the dropping backward of the trochanter, and the natural tendency of the foot to roll outward when unsupported. The head usually rolls down and back in the acetabulum.

In the impacted or incomplete fractures through the base of the neck the trochanter is usually displaced upward and externally rotated in relation to the proximal fragment. The appearance is one of marked coxa vara with anterior angulation of the neck.

Diagnosis.—In old persons the appearance is typical. The patient lies

Fig. 606.—Fracture near middle of neck, and good functional result may be expected with proper treatment. (Fracture Service, M. G. H.)

on the back obviously suffering severe pain. The hip is swollen and after the lapse of a day or two often presents ecchymosis. The leg is usually slightly adducted and externally rotated, often so much so that the outer border of the foot rests on the mattress. The appearance of the leg is such as to give the impression of absolute powerlessness. All motions of the hip are painful and abnormally free. When the leg is

rotated inward and released, it immediately drops back into the former position. The iliotibial band is relaxed.

In cases of impaction or fracture without complete displacement, movement of the hip is much less painful and is limited instead of being abnormally free. The movements chiefly restricted are those of abduction and internal rotation. Sometimes the patient can move the limb and may even walk.

Measurements from the anterior superior spines to the malleoli show shortening of the injured leg. The tip of the greater trochanter with reference to Nélation's line will be found abnormally high, while the base of Bryant's triangle is shortened. These latter measurements show that the shortening of the leg has occurred proximal to the trochanter.

In old persons the diagnosis is easy and usually can be made by a glance at the externally rotated foot. In younger persons the condition must be differentiated from fracture of the acetabulum with central dislocation of the head of the femur and from separation of the epiphysis. In the former condition the restriction of motion is usually much greater and palpation of the abdomen above Poupart's ligament, or rectal examination, may reveal the presence of a tender swelling. In the latter condition the age of the patient is the most suggestive feature.

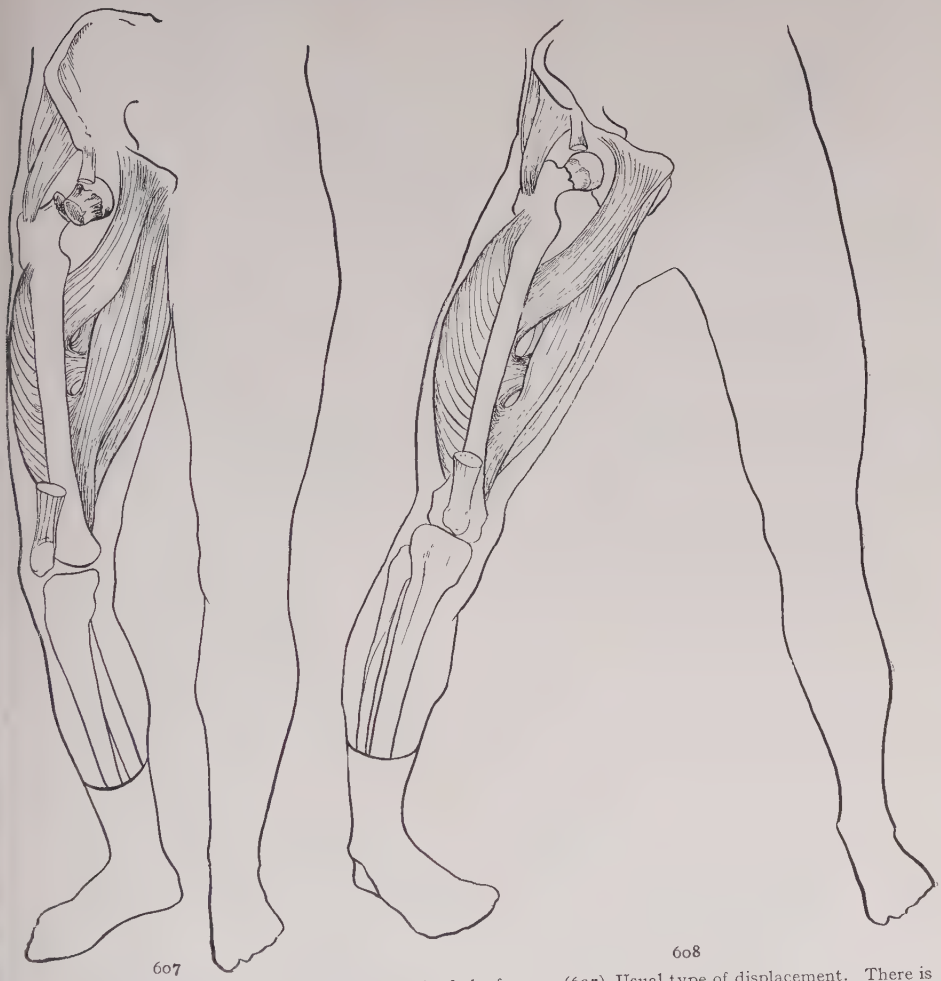
Roentgenograms are the final diagnostic aids. Attention should be called to the necessity of taking stereoscopic views. The flat plate often gives the appearance of impaction when there is complete separation with the distal fragment lying anterior to the cervical portion of the central fragment.

Treatment.—The matter of treatment must be considered from two standpoints, that of saving life, and that of ultimately restoring function to the hip. The first necessarily takes precedence over the second, but is usually only in question in patients of advanced years.

Old Age Fractures.—The treatment of cases of the latter type has always constituted a problem and probably always will. Many of the patients are already the victims of preëxisting constitutional disease and seem to be clinging to life with uncertain grasp. The shock of this severe injury and the complications which may ensue are likely to still further weaken their hold or entirely remove it. In such cases it is a well-established rule of treatment that prolonged recumbency, particularly in the dorsal decubitus, must be avoided, as tending to result in hypostatic congestion of the lungs and terminal pneumonia. The first aim must be to get the patient into the vertical position and out of bed if possible. In the past, such cases have been treated by support of the leg with sand bags or simple Buck's extension and have been transferred to wheelchairs at an early moment without regard to the needs of the fracture.

Yet in spite of these apparent life-saving measures the mortality rate has been high, Nix [8] reporting 16 per cent. in the Charity Hospital of New Orleans and Speed,[9] 18 per cent. at the Cook County Hospital.

Value of Fixation.—In centering attention on the first importance of



607 608

FIGS. 607 and 608.—Fracture of the neck of the femur. (607) Usual type of displacement. There is shortening and extreme external rotation of the leg. (608) Reduction by Whitman position of wide abduction and extension and internal rotation.

saving life, it is obvious that medical principles equally as well established as the first have been disregarded. These are that failure to immobilize a major fracture will of itself produce shock and that the continual movement of the fragments and the accompanying muscle spasm will result

[8] J. T. Nix, Jr., *New Orleans Med. and Surg. Journ.*, June, 1916.
[9] K. Speed. *ibid.*

in pain, which, when acting in an old, infirm person, may lead to exhaustion and death. Certainly nothing can be more striking than the transformation in the appearance of the patient brought about by complete

609

610

FIGS. 609 and 610.—Whitman method of reduction. (609) With the patient lying on a spica support the legs are supported by assistants and traction exerted. (610) When shortening has been completely overcome, as determined by actual measurement, the sound leg is completely abducted, following which the injured hip is internally rotated, extended and abducted to the extreme limit. The leg is then fixed in this position by the application of plaster.

immobilization of the seat of fracture in a plaster of Paris casing. From the day of its application the patient ceases to have pain, sedatives are no longer required, the appetite improves, and there is improvement in

the general condition. Contributing to this betterment is the ease with which the patient may now be handled, turned, and lifted. This makes it possible to change the position at frequent intervals and to lift the patient into a chair. The additional activity thus permitted is of benefit in keeping up the muscular strength, stimulating the circulation, and maintaining the morale.

Fixation in Relation to Recovery of Function.—On the other hand, when treatment is regarded from the standpoint of functional restoration of the hip, it is obvious that union of the fracture is the *sine qua non* of function and that the fragments will not unite unless complete reduction is obtained and adequate fixation provided. Thus Henderson [10] reports that in a group of 120 cases of ununited fracture of the hip examined at the Mayo clinic, a history of inadequate treatment was obtained in nearly all. Campbell [11] reports that in 44 similar cases seen by him the treatment had been as follows: by Buck's extension—14; by plaster casts for a short time—9; by Hodgen's splints—4; by fixation with sand bags—9; by osteopathy—2; and no diagnosis and no treatment in 5. True impacted fractures will unite with little or no treatment save relief from weight-bearing, but the same treatment when applied to unimpacted fractures certainly results in non-union.

The Whitman Method of Treatment.—To Whitman [12] of New York belongs the credit of having introduced the method which seems most satisfactorily to meet all the indications of treatment. The underlying principle is one of reduction and fixation. Under general anæsthesia the hip is manipulated into the position of complete abduction, hyperextension, and internal rotation, and immediately fixed by the application of a plaster of Paris spica casing. According to Whitman, reduction is accomplished by virtue of the fact that during the movement of abduction the greater trochanter is made to impinge against the acetabulum, and a fulcrum is thus provided by means of which the fragments are levered into position. Davis has pointed out that the trochanter never impinges against the acetabulum normally and, if this be the case, it is probably the "Y" ligament which furnishes the fulcrum. At any rate, as the long arm of the lever swings out, the short inner one swings down and in. Extension tightens both limbs of the "Y" ligament, while internal rotation winds the outer fragment in the posterior capsule and closely approximates the fractured surfaces.

Results.—This method, although apparently radical, is constantly being more widely adopted and in practice has reduced the mortality and given

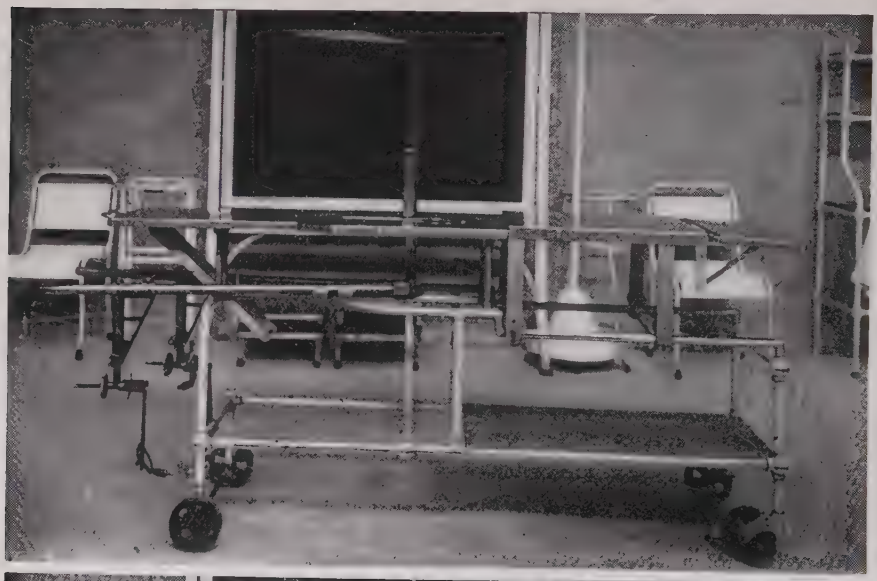
[10] M. S. Henderson, *Surg., Gyn. and Obstet.*, February, 1920. *Pennsylvania Med. Journ.*, April, 1920.

[11] W. C. Campbell, *Southern Med. Journ.*, August, 1920.

[12] Royal Whitman, *Annals of Surg.*, November, 1902, *Medical Record*, March 19, 1905.

excellent functional results. Campbell [13] has reported 79 cases with non-union in 10 per cent. More recently Murphy and Dorrance[14] have reported 25 cases in which the results were tabulated as follows: 9 obtained full function; 5 use a cane; all are able to walk about; 2 died, and of these,

611



612

one was unconscious on admission to the hospital. The authors are fully able from their own experience and that of their colleagues to endorse the effectiveness of the method and its general applicability even in persons of extreme age.

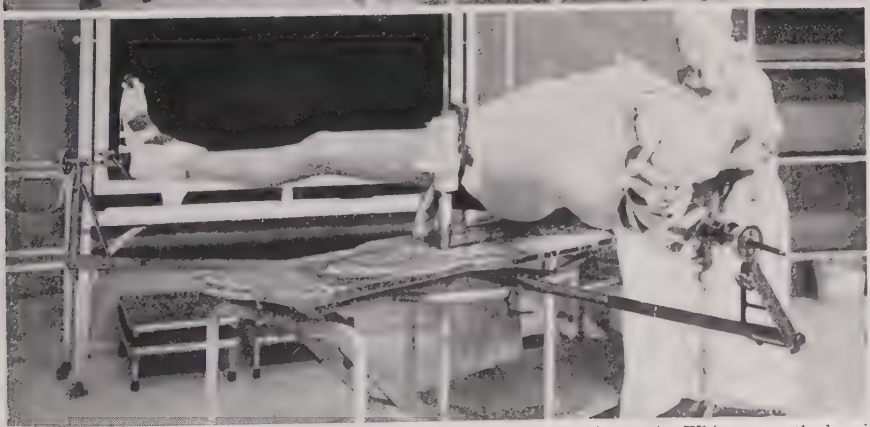
Technic of Reduction.—The procedure is as follows: Under general anæsthesia, with the patient lying on a solid spica support from which

[13] W. C. Campbell, *Annals of Surg.*, November, 1919.

[14] G. M. Dorrance and E. C. Murphy, *Penn. Med. Journ.*, April, 1922.

613

614



615

FIGS. 611, 612, 613, 614 and 615.—Reduction of fracture of the hip by the Whitman method, using a fracture table. (611) Fracture table (Hawley). (612) Patient placed on the table and traction obtained by attaching the feet to the traction stirrups by means of a loop of bandage in the form of a clove hitch passing about the ankle. (613) When the legs have been pulled down to full length, the uninjured leg is widely abducted, following which the injured hip is placed in the Whitman position. (614) Abundant padding of sheet wadding should be applied with special felt pads to protect the bony prominences. (615) Cast completed. At this stage, the traction is removed and the leg supported manually while the foot is enclosed in plaster. (Fracture Service, M. G. H.)

counter-traction may be obtained, traction is exerted on both legs by two assistants, each supporting a foot. When both legs are of the same length, as determined by comparative measurements, the uninjured one is abducted to its extreme limit to fix the pelvis and show the normal range of movement. While maintaining the traction, the injured leg is then internally rotated, the operator assisting in the replacement by lifting forward on the trochanter. The leg is then swung out into complete abduction, gentle force being used to overcome any resistance which may be encountered,

FIG. 010.—Reduction of fracture of the hip. While a fracture table is a convenience, it is not a necessity. Any spica support will serve satisfactorily or, when this is lacking, one may be improvised from an iron pail and wooden box as shown.

at the same time maintaining slight hyperextension at the hip. At this point the assistants may discontinue the traction and content themselves with maintaining the position during the application of the plaster. Flexion of the hip is a useful preliminary to the manipulation in order to free the anterior capsule and fibres of the psoas muscle which may have become interposed between the fragments.

Fixation.—Immobilization is obtained by the application of a long plaster of Paris spica extending from the toes to well above the rib margins. Abundant padding of the bony prominences is required. Some surgeons prefer to terminate the body portion of the cast just above the iliac crests in order to allow greater mobility of the spine, but in this case it is necessary to run the plaster down the opposite thigh to the knee in order to secure fixation of the pelvis. The former method is generally preferable, as it permits greater freedom of movement, the patient being able to assist himself with both hands and the uninjured leg. There is

no advantage in fixing both hips as well as the thorax, as adequate immobilization is obtained from the inclusion of one hip alone, and this procedure adds decidedly to the discomfort. An important detail is to moderately flex the knee of the injured leg during the application of the plaster, the lower leg thus serving as a crank to maintain the desired

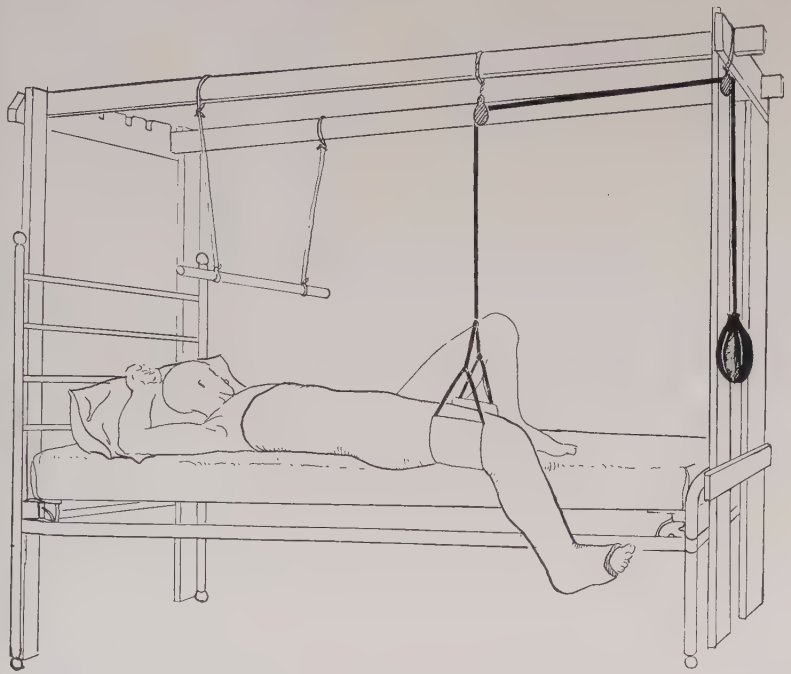


FIG. 617.—Drawing showing method of suspending the limb in fracture of the hip following the application of a plaster of Paris spica casing.

degree of internal rotation. The application of a good plaster of Paris spica which is light and comfortable and at the same time strong is of itself an operation requiring a considerable degree of skill, and the novice should not attempt it without assistance. The main requisites for success are plenty of help, a good spica support (a bucket may be used when no other means is available—see Fig. 616), plaster bandages with which the surgeon is familiar, and a trained person to wet them and make them ready for use.

Suspension.— The after-treatment is important. An overhead frame should be erected above the bed, by means of which the leg portion of the cast may be suspended, suspension being obtained by means of weights and pulleys. In addition a canvas hammock or sling should be passed beneath the body portion of the cast, the ends being attached to cords running over pulleys and fastened to heavy weights. This is intended to assist in lifting the body when the bedpan is used or when the back

is being cared for, and at other times may be discontinued. In addition, overhead handgrips should be provided by means of which with the assistance of the uninjured leg the patient may vary the position in bed at will.

General Care.—The head of the bed should be elevated twelve to sixteen inches in order to counteract the tendency of fluid to gravitate to

FIG. 618.—Fracture of the hip. Method of suspending the leg from an overhead frame after the cast has been applied. By the use of the overhead hand grips, aided by the uninjured leg, the patient is permitted a considerable range of movement in bed. (Fracture Service, M. G. H.)

the back of the lungs. Regularly, twice a day and oftener, if indicated, the patient should be turned on the face and allowed to remain in this position for at least an hour. This affords opportunity to inspect the skin of the back and by inserting the hands underneath the cast to bathe, dry, powder, and otherwise care for the skin. Constant vigilance is necessary during the first week or two to keep the patient in good general condition.

The fluid intake and urinary output during the 24-hour periods should be carefully noted, the effort being made to keep them at a level of at least 1200 cc. Liquids and soft solids should be given at frequent intervals, the bowels kept open with laxatives and enemata, and digitalis used if there is dyspnœa or cough.

Sitting Position.—At the end of a few days, if the general condition is good, the patient may be lifted into a chair. A straight-backed chair

FIGS. 619 and 620.—Plaster spica holding the hip in the Whitman position. Note the ease with which a sitting position may be obtained. (Fracture Service, M. G. H.)

with a fairly high and deep seat should be selected. The patient is placed on pillows with the weight resting on the buttock of the uninjured side and the leg enclosed in plaster projecting over the edge of the seat. Pillows are placed at the back and the patient fastened in place by a belt or folded sheet passing around the body and back of the chair and securely tied. In addition a sling of webbing or bandage is passed over the foot of the cast and fastened to the arm of the chair. A stool is required for the uninjured foot. The sitting position should be permitted for only a short period at first and the time gradually increased as the strength improves. Usually the patient quickly learns to stand on the uninjured leg, pivot about and drop into the chair, so that after a short time very little assistance is required.

621

622

623

FIGS. 621, 622 and 623.—Ambulatory method of treating fracture of the hip. (621) The Bradford abduction splint applied to the skeleton, showing function of the abduction arm which presses against the opposite ischial tuberosity and thus maintains abduction of the injured hip. (622) The Bradford abduction type of caliper brace. Anterior view. (623) Same, posterior view.

Length of Fixation.—Immobilization must be continued for a long time, an arbitrary period of three months being safe. Attempts to shorten this period are likely to cause regret. Usually it is unnecessary to change the original cast, the plaster being trimmed away or openings cut over painful pressure points in case these develop. In extreme instances the casing may have to be split on two sides and the halves removed separately in order to care for the skin, but a certain amount of fixation is inevitably lost in the process.

Convalescent Brace.—Following the removal of the plaster at the end of three months, the callus is soft and, while able to withstand the strain of ordinary movement, is likely to give way if subjected to active weight-bearing. At the same time active use is desirable to stimulate the circulation and counteract bone atrophy. The use of a Thomas ring caliper brace provides the best means of meeting this difficulty. It consists of two vertical steel supports on the inner and outer sides of the leg, respectively, fastened above to a padded steel ring which encircles the root of the thigh and thrusts upward against the tuberosity of the ischium. The lower ends of the steel uprights are bent to a right angle and inserted in a socket in the heel of the shoe. The length of the splint should be so adjusted that when the patient stands the heel of the shoe is pushed slightly away from the heel of the foot and a considerable amount of the body weight is transmitted from the ischial tuberosity to the top of the brace and thence to the ground. A knee-joint with a lock may be provided to permit flexion of the knee when sitting. Walking is usually facilitated by elevating the sole of the opposite shoe one inch in order to compensate for the inability to flex the knee of the injured leg when taking a step. With such an apparatus full weight-bearing, at first with the aid of crutches and later with canes, may be permitted without harm.

Full Weight-bearing.—The length of time during which the fracture should be thus protected is uncertain and varies with the type of case. With a fracture of the proximal portion of the neck, the period must certainly be long, and we have observed bending of the neck and the development of coxa vara deformity as late as nine months after the injury. In general, full weight-bearing should not be permitted before the end of twelve months. We wish particularly to emphasize the need for prolonged protection, as many potentially good results have been spoiled by the abandonment of caution at a time when a little greater patience would have gained excellent function. When a Thomas caliper brace is not available, it is necessary to use crutches for the designated period. This involves greater risk, as a slip or fall is likely to result in fresh injury of the hip, and constant vigilance is necessary to avoid this.

Physiotherapy.—Following the removal of the plaster the joints of the ankle, knee, and hip must be mobilized, the circulation reëstablished, and

624

625

FIGS. 624 and 625.—Fracture of the neck of the femur in woman of sixty-four years. (624) Before reduction. (625) Following reduction and immobilization in the Whitman position in plaster.

the strength of the muscles restored. Active physiotherapeutic measures, such as baking, massage, and active exercises, should be employed. During the first week or two it is well to keep the patient in bed, as progress is more rapid and the discomfort less. The movements of the ankle and hip return fairly rapidly, but those of the knee are more obstinate and are benefited by treatment. Marked swelling of the foot and lower leg

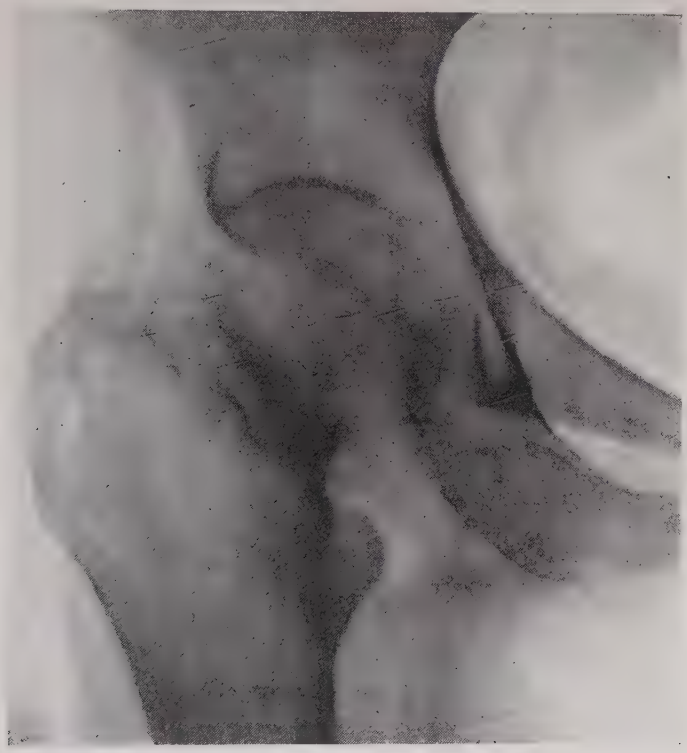


FIG. 626.—Fracture of the neck of the femur in woman of 64 years. End result one year after fracture, solid bony union, shortening of the neck, but perfect function.

persists for a considerable period and is relieved by massage and the use of an elastic bandage.

Roentgen Examination.—Beyond establishing the diagnosis, roentgen examination is of little value in the early phase of treatment. Reduction by the Whitman method is accomplished in a very positive manner, and if the manipulation is performed with careful attention to detail and comparison made with the uninjured side, one may be fairly sure of good position. The only likely cause of failure is interposition of tissue, and this does not show in the roentgenogram. In aged patients, unless the position is notably bad, as can be more readily determined from the attitude of the limb, it is doubtful whether one would be justified in

627 628

FIGS. 627 and 628.—Central type of fracture of the neck of the femur. (627) Before reduction. (628) Same case after reduction and immobilization in plaster in the Whitman position. (Fracture Service, M. G. H.)

removing the plaster and subjecting the patient to a second manipulation on the basis of slight lack of approximation as indicated by the roentgenogram alone. On the other hand, roentgenological evidence of union is not obtainable until long after clinical examination has demonstrated its presence, and during this period roentgen examination is of value only in demonstrating that the fragments are approximated. Except in the case of fracture of the base of the neck, bony union rarely shows before the end of nine months, and while it is a satisfaction to have its presence demonstrated, at the same time one should remember that the only test of value is the functional one and that strong fibrous union frequently gives as good results as bony union. When dealing with young, vigorous patients the case is different and the position of the bones should be carefully checked by roentgen examination, as operative reduction and fixation is a preferable alternative to imperfect alignment.

Anæsthesia.— The matter of administering an anæsthetic for the reduction of the fracture will have to be settled for each case. Without anæsthesia the pain is excessive, and it is doubtful if complete reduction can be accomplished in the presence of muscle spasm. Ether is well tolerated by all patients except those of extreme age or others with a preexisting bronchitis or chronic passive congestion of the lungs. In these cases we are in the habit of employing spinal anæsthesia, and have found it safe and highly satisfactory.

The Combined Traction Method.—The only other method of treatment which may in any sense be considered as an alternative to the Whitman method is the one introduced many years ago by Maxwell and since advocated by Ruth.[15] It consists in the application of combined longitudinal and lateral traction to the leg, the latter arranged in such a way as also to maintain internal rotation of the hip (see Fig. 594). The resultant of the two forces acting at right angles to each other is represented by a line passing between the two and corresponds more or less closely to the normal axis of the neck of the femur. Traction in this line should, of course, secure and maintain reduction. Preliminary manipulation is performed to free interposed tissue and bring the fragments into approximation. This consists in flexing and extending the hip, exerting traction in the axis of the limb, and internally rotating the leg. Very good results have been reported, but in our estimation the Whitman method presents so many advantages from the standpoint of caring for the patient, and the results with it have been so favorable, that we prefer it whenever possible. Bradford's[16] method of ambulatory treatment affords another alternative. He applies an abduction traction splint (Fig. 621), and

[15] C. E. Ruth, *Journ. A. M. A.*, December 3, 1921, p. 1811.

[16] E. H. Bradford, *Journ. Orth. Surg.*, August, 1919, p. 465; L. S. Kemp, *Surg., Gyn. and Obstetrics*, 1922, Vol. 34, p. 266.

629

630

FIGS. 629 and 630.—Fracture of the hip without displacement. When it is inadvisable to break up an impacted fracture or when there is practically no displacement, the hip may be fixed in the position of abduction and flexion as shown. This is a much easier sitting position and promotes the comfort of the patient while providing adequate protection. (629) Cast applied. (630) The patient sitting. A portion of the foot piece has been cut out to permit movement of the ankle. (Fracture Service, M. G. H.)

permits the patient to be about with crutches after the shortest possible period of recumbency, usually two to four weeks. The writers have tried this method but are not yet convinced of its advisability, although Bradford has reported excellent results.

Impacted Fractures.—Impacted fractures of the neck of the femur constitute a special group from the standpoint of treatment. In over 90 per cent. of such cases the injury is situated at the base of the neck close to its junction with the shaft, a region which on account of the plentiful blood supply is much more favorable for union than the proximal portion of the neck. As a matter of fact, fractures in this location unite rapidly and readily, and non-union is quite exceptional. Therefore, the only problem in such cases is to decide whether one will attempt to correct the deformity, which involves the risk of breaking up the impaction and the necessity of prolonged plaster fixation, or whether one will be content with letting well enough alone and follow a policy of simple immobilization. There can be no single solution of this problem, and the matter must be decided individually for each case, taking into full consideration the age and general condition of the patient, the location of the fracture, the amount of deformity, and the degree of impaction.

Fixation without Correction of Deformity.—In the case of very feeble or aged patients we are inclined to preserve the impaction, if this is well marked, even at the expense of considerable deformity. Such cases are adequately treated by the application of a plaster of Paris spica extending upward to the rib margin and downward to the knee. In view of the impaction, the position of the hip is unimportant, and it should, therefore, be fixed in the position of greatest comfort for the patient. Flexion of 45 degrees promotes ease in sitting and this is the position we are in the habit of using, the hip being slightly abducted (10 to 15 degrees) and neither externally nor internally rotated. Immobilization is maintained for about eight weeks and usually weight-bearing may be permitted at the end of four months, this depending upon the demonstration of firm callus by roentgenogram.

Reduction of Impacted Fractures.—When the patient is of a more robust type and the fracture is accompanied by considerable deformity, this should be corrected by the Whitman method of reduction and fixation. As a matter of fact, if the manipulation be performed gently and with care, the impaction is not necessarily completely broken up nor the fragments entirely separated. Usually enough impaction persists to maintain the approximation, and in any case union may be expected to take place promptly. Immobilization is obtained, as in the case of fracture of the proximal portion of the neck, by the application of a long plaster spica holding the hip in the position of full abduction, extension, and internal

631

632

FIGS. 631 and 632.—Open reduction of fracture of the neck. (Patient a young adult.) (631) Before reduction. (632) Fixation with a steel nail. The [illegible] of the [illegible] by the [illegible] of internal fixation is rarely required since the natural action of the Whitman method.

rotation. Solid, bony union demonstrable by the roentgenogram is usually present in four to six months, at which time weight-bearing may be permitted.

Fracture in Young Adults.— A distinction in the general policy of treatment should also be made in the case of fracture of the femoral neck,

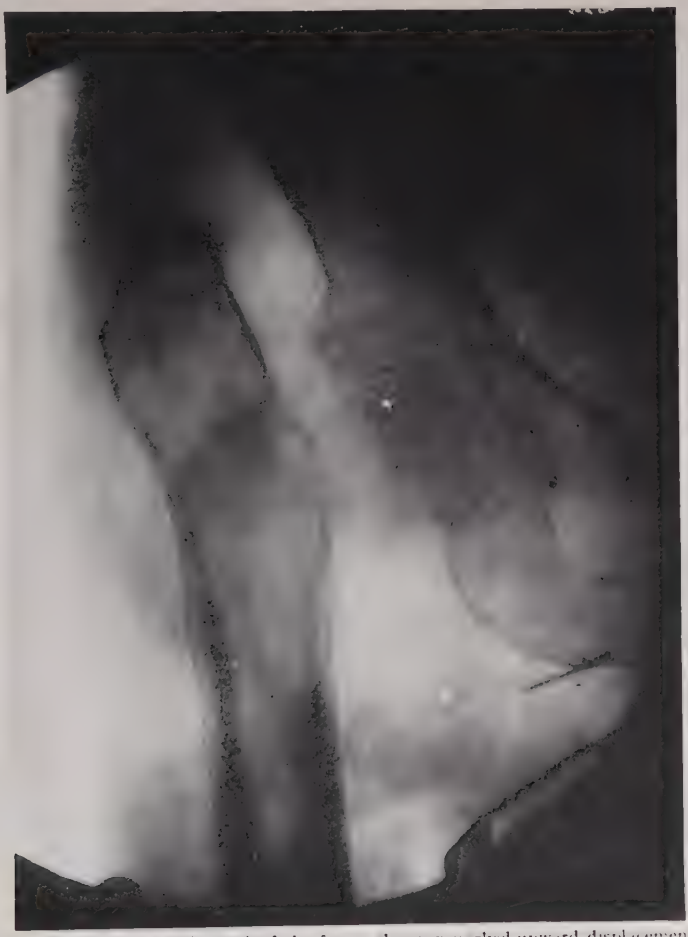


FIG. 633.—Ununited fracture of the neck of the femur showing marked upward displacement of the shaft and absorption of the neck. (Fracture Service, M. G. H.)

occurring in young and vigorous adults. The conditions here are favorable for union irrespective of the location of the fracture, provided that perfect approximation of the fragments and complete anatomical reposition are obtained. If these are not secured by the Whitman method of reduction and fixation, as determined by careful stereoscopic roentgenograms, then open operative reduction should be considered. The operation itself is difficult and should be undertaken only by an experienced

surgeon who is thoroughly familiar with the region of the hip, and the best of modern surgical facilities must be available. In case either of these is lacking, it is far better to follow the conservative plan of treatment and avoid the risk of disaster.

Operative Treatment.—Exposure of the seat of fracture is best obtained

FIG. 634.—Brackett's operation, showing the shaft implanted in the head and the trochanter displaced downward. (Fracture Service, M. G. H.)

by the Smith-Petersen incision, which, beginning at the anterior superior spine of the ilium, extends downward on the anterior surface of the thigh, a distance of 8-12 cm., and above is prolonged backward along the crest of the ilium to a point about two-thirds of the distance to the posterior superior spine. The dissection passes downward to the neck of the femur in the plane between the tensor fasciæ femoris and the sar-

torius muscles, and the tissues attached to the ilium are reflected subperiosteally as a musculo-cutaneous flap exposing the upper border of the acetabulum. The capsule is then opened and the region of the fracture exposed. Reduction is accomplished by combined external manipulation of the leg and internal manipulation of the fragments. With the bones in correct alignment it will usually be found that the reduction is well maintained by the Whitman position and that fixation by internal means is unnecessary. In this case the wound should be closed immediately and a long plaster spica applied, the leg being carefully supported by an assistant. When internal fixation is required, a beef-bone peg or nail may be driven into the neck through the trochanter, but this considerably increases the difficulty and hazard of the operation and should be avoided whenever possible. The after-treatment consists of immobilization in plaster for three months and the use of a Thomas caliper splint for three to four months longer until union is demonstrable by roentgenogram. If non-absorbable, fixative material is inserted in the bone, this should be removed at the end of about three months.

Prognosis.—As long as fracture of the neck of the femur remains chiefly an old-age injury, the general outlook will remain serious. No one method of treatment is likely to prove a complete panacea, and in spite of the very best care a certain number of failures will result. Nevertheless, it seems clear that with more vigorous treatment, and particularly by the more general use of the Whitman procedure, the results can be improved not only as regards the prolongation of life, but also the later restoration of function. Failure to obtain osseous union in old patients is not of itself a cause for disappointment, provided that strong, fibrous union is obtained instead.

Complications.—The complications which may occur are those chiefly incident to old age, such as bronchopneumonia, uremia, cardiac failure, cystitis, pyelitis, bed-sores and the like, and require no special consideration here.

Ununited Fractures.—The surgeon is frequently consulted by patients with ununited fracture of the neck of the femur, the majority giving a history of incomplete reduction, insufficient immobilization, or inadequate treatment at the time of the original injury. What to do for these cases constitutes an important surgical problem, the choice lying between palliative measures and radical operative procedure, and the final decision depends chiefly upon the general state of the patient's health. Palliative treatment is more or less unsatisfactory and consists in the application of a brace, either of the Thomas caliper type with a lock-joint at the knee or a steel, reinforced leather spica with a lock-joint at the hip. Operative treatment, on the other hand, involves considerable risk and is not always certain in its results, but should be advised when the general condition

and strength of the patient are good and a favorable outcome may be expected. Three operative procedures are available, each adapted to different conditions.

Bone-graft Operation.— 1. The fractured surfaces are freshened, approximated, and fastened together by a bone graft in the form of a peg driven through the trochanter into the neck. Davison [17] uses the upper portion of the shaft of the fibula because of its greater size and strength in comparison with a graft taken from the tibia. The technical difficulty of inserting the graft in the correct position is considerable, and the Roentgen ray may be employed with advantage during the operation

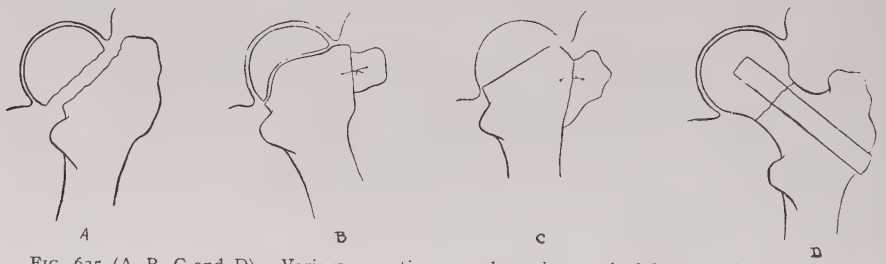


FIG. 635 (A, B, C and D).—Various operative procedures in ununited fracture of the neck of the femur. (A) Ununited fracture with neck completely absorbed. (B) Brackett's operation. The greater trochanter is removed and the end of the shaft transplanted directly into the head of the bone. The trochanter is reattached to preserve its muscle insertions. (C) Whitman's operation. The head of the femur is removed and the end of the shaft placed directly in the acetabulum, the trochanter being transplanted downward on the shaft. (D) Bone-graft method.

as advised by Campbell.[18] Another difficulty is constituted by the frequent, almost complete absorption of the neck of the bone. This prevents approximation of the fractured surfaces on account of the impingement of the trochanter against the rim of the acetabulum, and it is either necessary to adduct the leg to bring the fragments together or to leave a space between them and depend upon the graft to bridge it and ultimately become strong enough to bear the body weight.

Brackett's Operation.—2. The Brackett [19] operation avoids this difficulty by removing the tip of the great trochanter with its muscle insertions, rounding off the top of the shaft, and implanting this in the hollowed-out under-surface of the head. The trochanter is then reattached to the shaft at a lower level. Very good functional results have been obtained by this operation, and aside from the immediate risk the only danger lies in the possibility of the bones failing to unite.

Whitman's Operation.— 3. Whitman's [20] operation, although resembling somewhat the Brackett procedure, utilizes an entirely different principle. The central fragment, including the head of the femur, is entirely removed

[17] C. Davison, *Journ. A. M. A.*, September, 1921, p. 916.
[18] W. C. Campbell, *Journ. A. M. A.*, September 17, 1921, p. 916.
[19] E. G. Brackett and Way Sung New, *Boston Med. and Surg. Journ.*, September 13, 1917, p. 351.
[20] R. Whitman, *Surg., Gyn. and Obstetrics*, June, 1921.

from the acetabulum and the top of the shaft implanted there to form a false joint. The portion of the neck attached to the distal fragment is saved and its length increased by removing the greater trochanter on a line continuous with its upper surface. The latter with its attached muscles is reinserted at a lower level on the shaft of the femur in order to provide a new point of leverage. The advantages of this operation are that it does not depend for its success upon the patient's power of bony union, that it requires only a short period of immobilization (four to six weeks), and that it is applicable when the joint itself is affected. It is particularly adapted to aged or infirm patients with feeble reparative processes and in whom a rapidly executed operation and a short period of fixation are important.

V. INTERTROCHANTERIC FRACTURE OF THE FEMUR

Occurrence.—Intertrochanteric fracture of the femur is similar both in mode of production and type of displacement to fracture of the base of the neck, with which injury it is frequently grouped. It is of fairly common occurrence and is likewise an old-age fracture. Figures from the Cook County Hospital, reported by Speed,[21] indicate that it carries a high mortality, equal, in fact, to that of true fracture of the neck, although our own experience does not bear this out.

Pathology.—The fracture line usually coincides quite accurately with the anterior oblique line connecting the two trochanters. True separation of the fragments is exceedingly rare, and impaction of greater or less extent is the rule. Displacement is either absent or of slight degree, and when present consists of a flattening of the angle made by the neck with the shaft and the production of coxa vara deformity. The appearance is as if the head and neck had bent downward, hinging at the intertrochanteric line. Because the line of fracture passes through spongy bone with ample blood supply, healing occurs promptly and non-union is very rare.

Treatment.—The treatment resembles that of fracture of the base of the neck. When there is no deformity, simple protective splinting with a plaster of Paris spica holding the hip in the position of comfort is all that is required. When displacement is present, the deformity should be corrected by manipulating the hip into the position of full abduction in order to restore the proper angle of the neck. This must be done under general anæsthesia. Cases without displacement may also be treated by traction in a Thomas splint with the advantage of permitting massage of the muscles of the thigh and mobilization of the hip joint. The hinged knee attachment should be used in conjunction with the splint to prevent

[21] K. Speed, *Surg., Gyn. and Obstet.*, June, 1921.

636 637

FIGS. 636 and 637.—Roentgenogram of intertrochanteric fracture. (636) Before reduction. (637) Following reduction by internal rotation and abduction of leg and fixation in Thomas splint.

internal rotation of the limb. Union is usually fairly solid in eight to ten weeks, at which time protected weight-bearing in a caliper splint may be permitted. Full weight-bearing may usually be allowed at the end of four to six months.

VI. PERTROCHANTERIC FRACTURE [22] OF THE FEMUR

Nature of the Injury.—In this injury the fracture line passes more or less transversely across the upper end of the shaft of the femur, beginning on the mesial side above the lesser trochanter and terminating on the outer side below the greater trochanter. The lesser trochanter is either attached to the distal fragment or is torn loose and constitutes a third fragment. Slight comminution is often present. The injury itself is quite rare and is produced by indirect violence causing hyperextension of the thigh. The "Y" ligament checks this movement and by tension on the anterior surface of the neck protects this portion from injury. The strain thus falls chiefly at the point of attachment of the ligament, and this determines the location of the fracture.

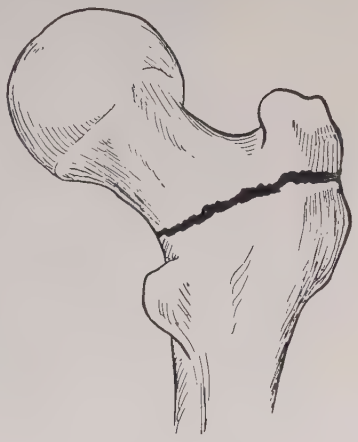


FIG. 638.—Diagram illustrating pertrochanteric fracture.

Treatment.—Although more or less displacement is common, this is usually not of a type to cause serious interference with function, provided the normal angle of the neck of the femur is maintained. Serious displacement requires treatment by traction with the hip flexed and abducted, and whether this is obtained by the skeletal method with calipers or by adhesive skin traction (see pp. 538, 539) depends upon the extent of the displacement and the type of patient. Slight displacement may usually be corrected by manipulation of the hip and fixation in a plaster of Paris spica, the position being one of flexion and abduction. Prompt healing may be expected, union being solid in eight to ten weeks.

VII. FRACTURES OF THE TROCHANTERS

Fracture of the Greater Trochanter.—The greater trochanter is occasionally fractured as the result of direct violence from a blow or fall on the lateral aspect of the hip. A crushed, comminuted type of fracture involving the tip of the trochanter is the usual type of lesion, and complete separation of the fragments is exceedingly rare. The injury causes only slight

[22] Wilensky, "Pertrochanteric Fractures of the Femur," *Surg., Gyn. and Obstetrics*, 1920, xxx, p. 244.

disability, and the patient is usually able to walk. Treatment consists of protective splinting and the early use of physiotherapeutic measures. A plaster of Paris spica extending from the rib margin to the knee and hold-

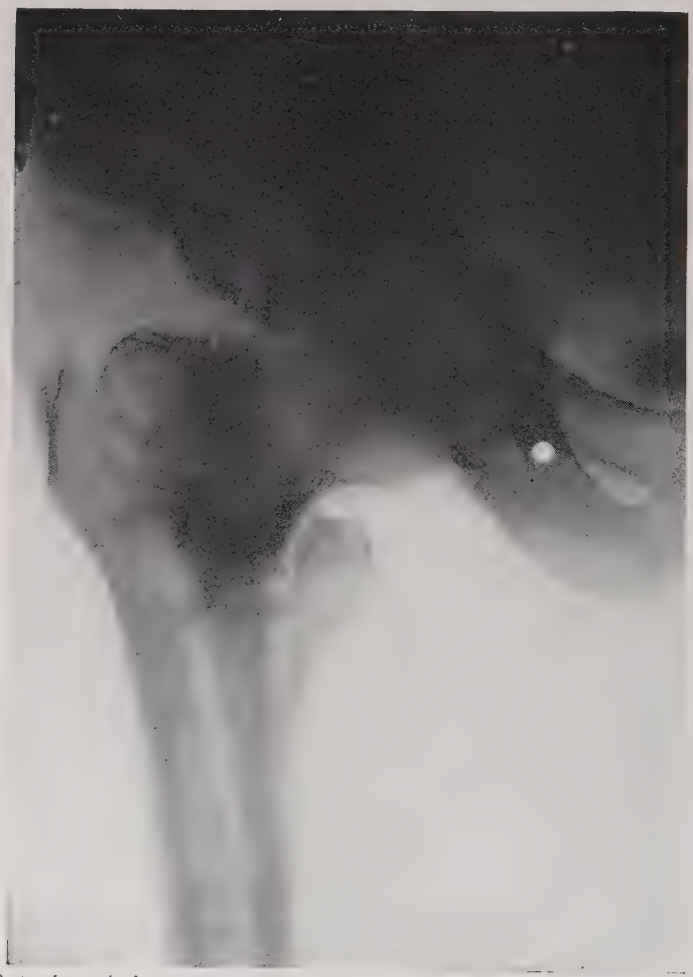


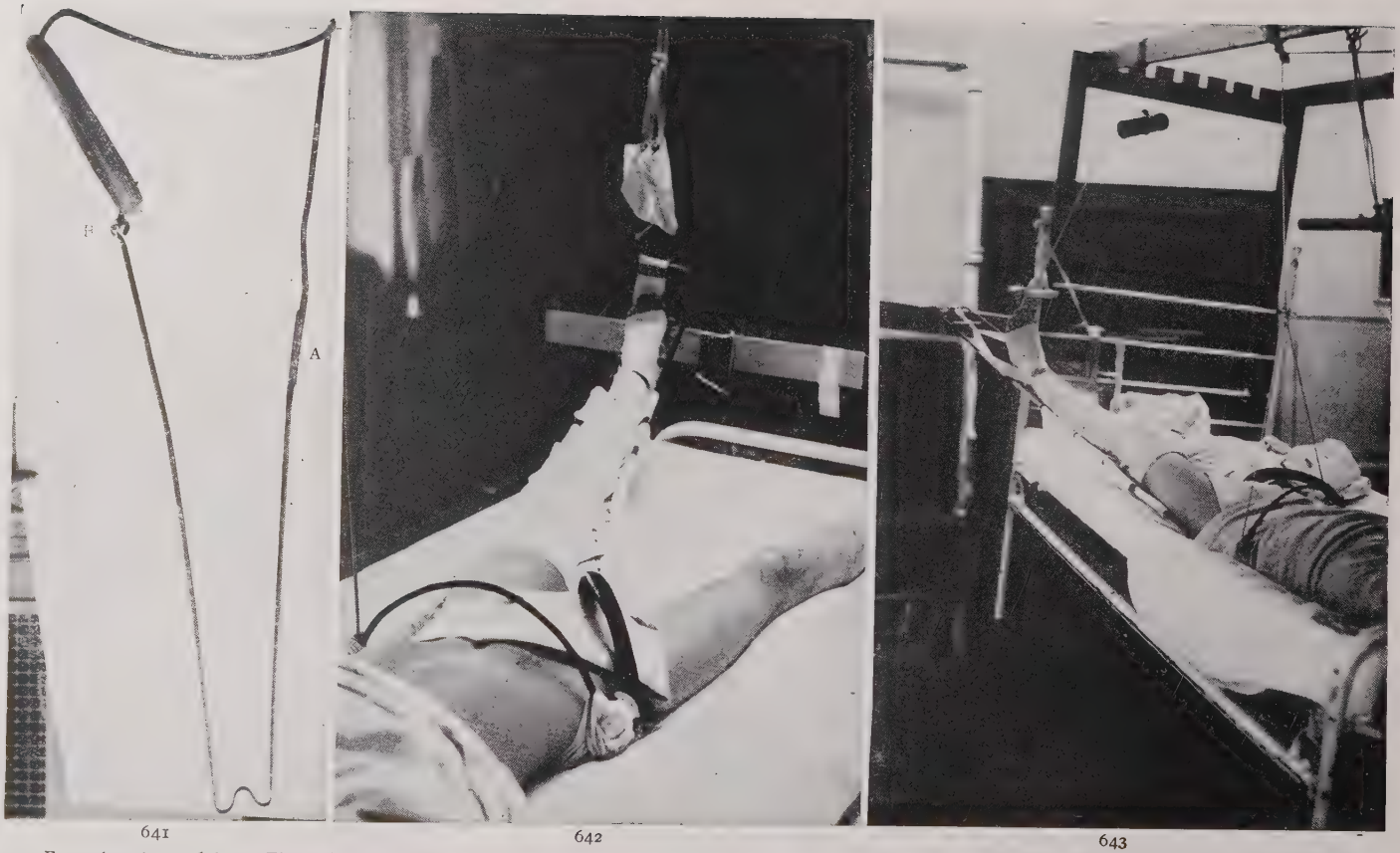
FIG. 639.—Pertrochanteric fracture (comminuted). Before reduction. Note flattening of the neck and shortening. (Fracture Service, M. G. H.)

ing the hip in moderate abduction and slight flexion usually meets the need. The cast should be split within a few days, and baking, massage, and mobilization of the hip begun. Following each treatment the plaster casing is replaced, the two portions being strapped together. Crutches may be permitted from the first, but active weight-bearing with the injured leg should be avoided until the end of four to six weeks. Complete functional recovery should be expected.

Fracture of the Lesser Trochanter.—Fracture of the lesser trochanter is a rare injury, only a few cases having been reported. Muscular violence apparently plays the chief rôle in its production. Displacement of con-

FIG. 640.—Pertrochanteric fracture (comminuted). Alignment restored, shortening overcome by traction in Thomas splint. (Fracture Service, M. G. H.)

siderable degree from the action of the iliopsoas muscle has been observed, necessitating operative reduction and suture for its correction. Fixation of the hip in the position of flexion to secure relaxation of the attached muscles would seem a logical part of the after-treatment.



641 642 643

FIGS. 641, 642 and 643.—The abduction traction splint. (Crile.) This is very useful in cases of injury of the hip complicated by the presence of wounds which require dressing. (641) Photograph of the splint. Note the lengthening attachment at A, and the hinge at B, by means of which the amount of abduction may be altered. (642) Splint applied, showing ring encircling the base of the uninjured leg. (643) Splint applied and suspended.

Compound Injuries of the Hip.—Compound fractures in the region of the hip are exceedingly rare except as a result of gunshot wounds. Compound dislocations are encountered even less frequently and can result only from great violence. The treatment of the wound should follow the lines already indicated in the chapter on "Compound Fractures," efforts being centred in the fresh case on the prevention of infection, in the late infected case on the provision of adequate drainage. The hip must be immobilized in the position of abduction. Plaster of Paris is of little service when there is a large draining wound. For such a case the Crile abduction traction splint (Figs. 641-643) will be found of value. This is a modification of the Thomas leg splint, counter-extension being obtained from the ischium on the unaffected side by means of a padded leather-covered ring which encircles that thigh. The splint is prolonged upwards to include the pelvis and lower trunk, to which it is fixed by a muslin or canvas sling passing under the back. Ready access to the wound is thus made possible.

CHAPTER XV

FRACTURES OF THE SHAFT OF THE FEMUR

ANATOMICAL CONSIDERATIONS

The Femoral Shaft.—The shaft of the femur presents a very definite bowing with the convexity forward and outward (Fig. 644), and restoration of this curve following fracture is essential in order to preserve the normal alignment of the articulations and the proper function of the muscles. The concave side of the femoral shaft is strengthened posteriorly by the linea aspera, which near the lower third of the bone divides into the poorly-defined supracondylar ridges. The inner ridge is interrupted near its middle by a space for the passage of the femoral vessels and terminates below in the prominent adductor tubercle.

Nearly cylindrical on cross section at its middle, and composed of strong, compact bone, the shaft is more quadrilateral in shape in its lower third, and the structure more cancellous. In spite of the fact that the femur is strongest near its middle, it is this portion which is the most frequent site of fracture, at or about the point of greatest convexity of the forward curve (Fig. 648).

The Fascial Arrangement.—The thigh muscles are divided into three main groups: the extensors, flexors, and adductors, each separated from the others by intermuscular septa which pass inward as prolongations of the deep fascia to be attached to the linea aspera (Fig. 645). The lateral intermuscular septum separates the vastus lateralis from the short head of the biceps, and the medial inter-muscular septum separates the adductor and extensor compartments and forms the fascial floor of Hunter's Canal.

The Extensor Muscles.—The extensor group consists of the quadriceps extensor, which is composed of the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius or cruræus muscles. They are inserted by a common tendon into the upper border of the patella and by lateral expansions into the upper end of the tibia. The adductor group is formed by four muscles: the gracilis, adductor longus, adductor brevis, and adductor magnus.

The Hamstrings.—The posterior compartment of the thigh contains the hamstring muscles, consisting of the biceps, semitendinosus and semimembranosus. They all arise from the tuberosity of the ischium, the biceps having an additional point of origin by means of its short head from the posterior surface of the femur, and are inserted near the upper end of the tibia and fibula, being jointly responsible for flexion of the knee. They are supplied by the sciatic nerve, which proceeds distally, at first lying on the posterior surface of the adductor magnus and then occupying the groove between the short and long heads of the biceps before entering the popliteal space.

The remaining muscles of importance in relation to fractures of the shaft of the femur are the iliopsoas inserted into the lesser trochanter, which may cause flexion of the upper fragment, and the group of short external rotator muscles of the hip, which tend to rotate the proximal fragment outward. Finally, the attachment of the gastrocnemius to the lower end of the femur determines largely the backward tilting of the lower fragment in fractures of the lower third.

The Vessels.—The main vessels are nowhere in danger of injury from the fracture itself, except in the lower third of the thigh and the popliteal space, where they may be pressed upon by the backwardly tilted lower fragment. They are very adequately protected by the considerable pad of fat normally present in this situation which intervenes between the vessels and the bone.

FRACTURES OF THE SHAFT OF THE FEMUR

General Considerations.—Fracture of the femoral shaft is a major type of injury when it is considered from the standpoint either of its immediate or remote effects. The fresh injury is frequently attended

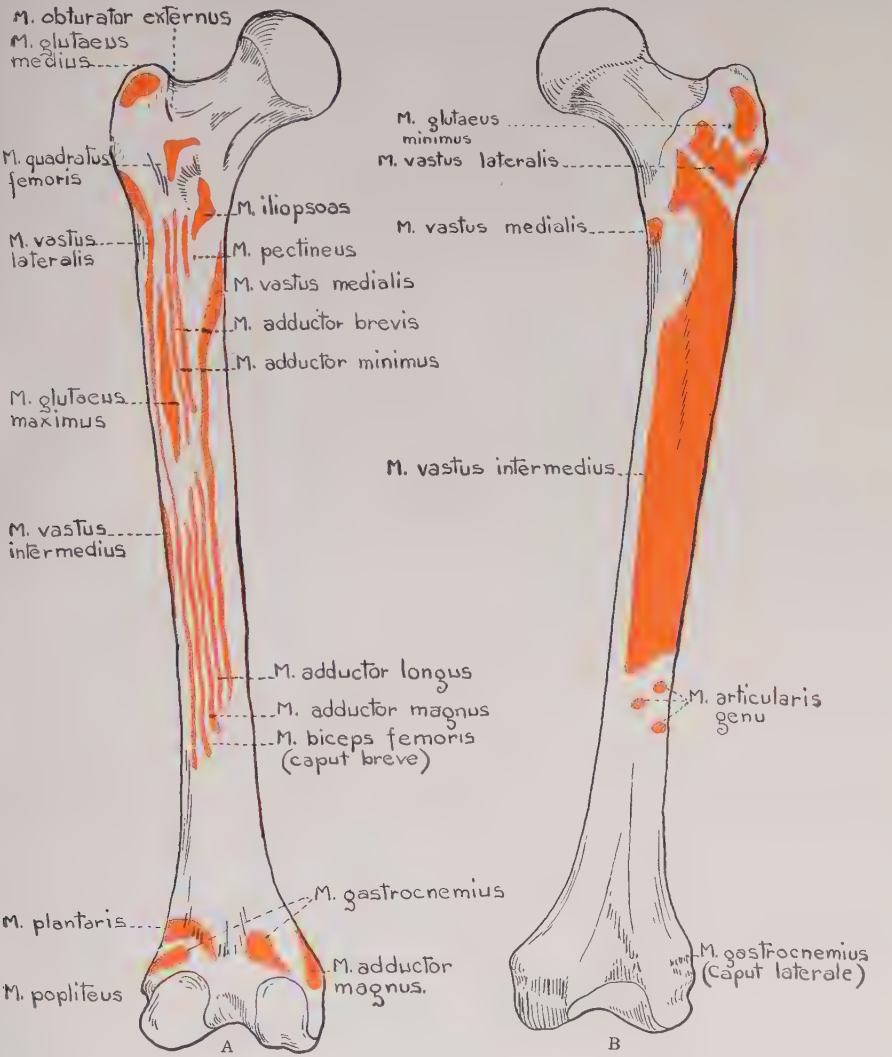


FIG. 644 (A, B).—Outline drawing of the anterior and posterior surfaces of the femur, showing the points of muscle attachment. (A) Anterior view. (B) Posterior view.

by severe shock, which in the more serious cases, particularly those with the crushed, comminuted type of fracture, may endanger life. Gangrene may supervene if there is accompanying blood-vessel injury. In bad compound fractures hæmorrhage and infection are both real dangers,

and in the gunshot injuries of the war caused a mortality during the first two years of 50 per cent. The remote effects include healing with bony deformity, such as shortening and angulation, interference with joint function due to adhesion or traumatic arthritis, paralysis from nerve injury, and many other related conditions, practically any of which may result in permanent crippling or disablement. To avoid these dangers,

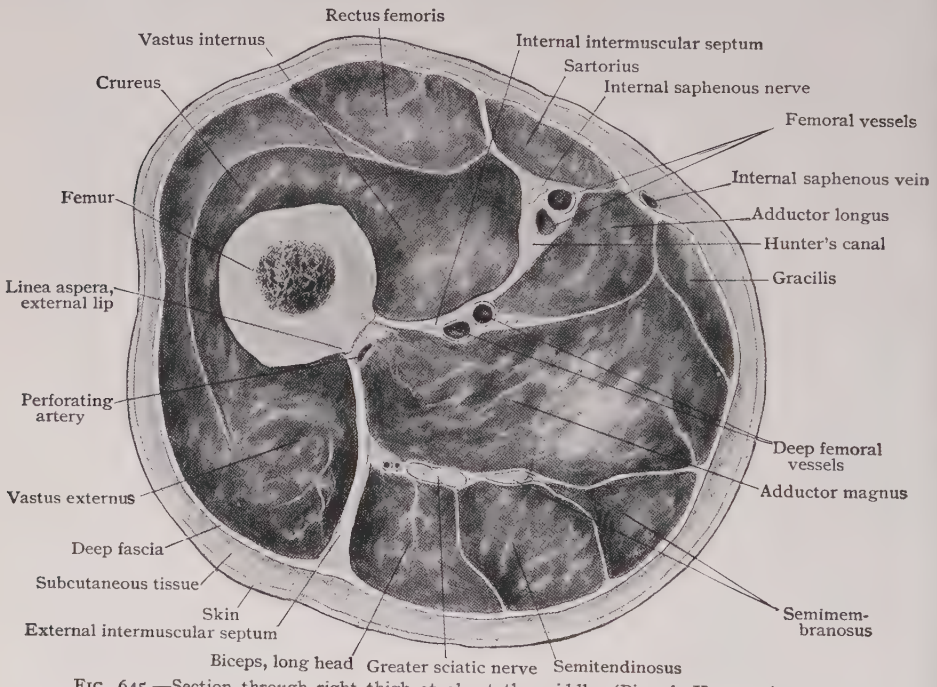


FIG. 645.—Section through right thigh at about the middle. (Piersol: Human Anatomy.)

the most painstaking care is required, and both because of the necessity of providing the very best facilities and the serious character of the injury, it is one that imperatively demands hospital treatment whenever possible.

Occurrence.— The fracture occurs with considerable frequency and may affect any portion of the shaft. The most common site is in the middle third or at the junction of the upper and middle thirds. Either direct or indirect violence may be the causative agents, the trauma in both cases being of a severe nature, but the former is much the more common. Direct violence is more apt to cause a transverse type of fracture or one with comminution, while indirect violence, if of the bending type, causes the long, oblique variety of fracture, or, if of the twisting or torsion type, produces the spiral variety of fracture, the latter being relatively uncommon. Persons of any age may be injured, but the great majority of such accidents affect either vigorous adults between the ages of eighteen

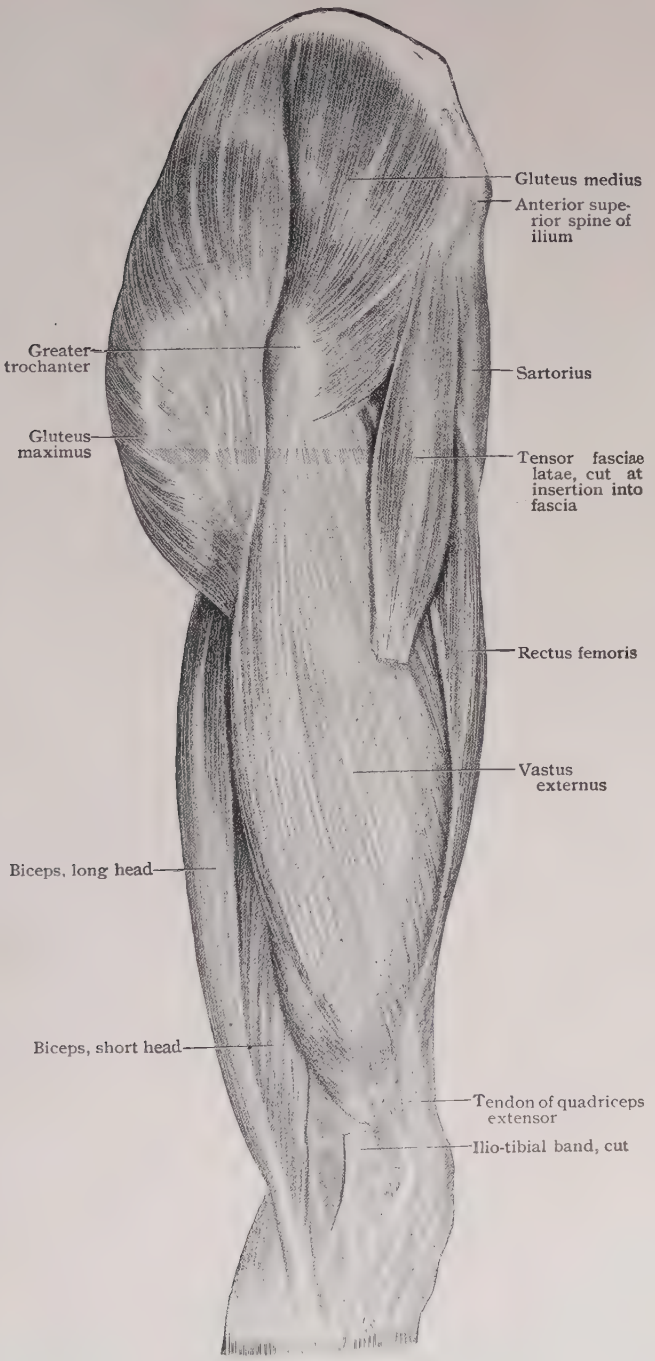


FIG. 646.—Muscles of the right thigh, lateral aspect. (Piersol: Human Anatomy.)

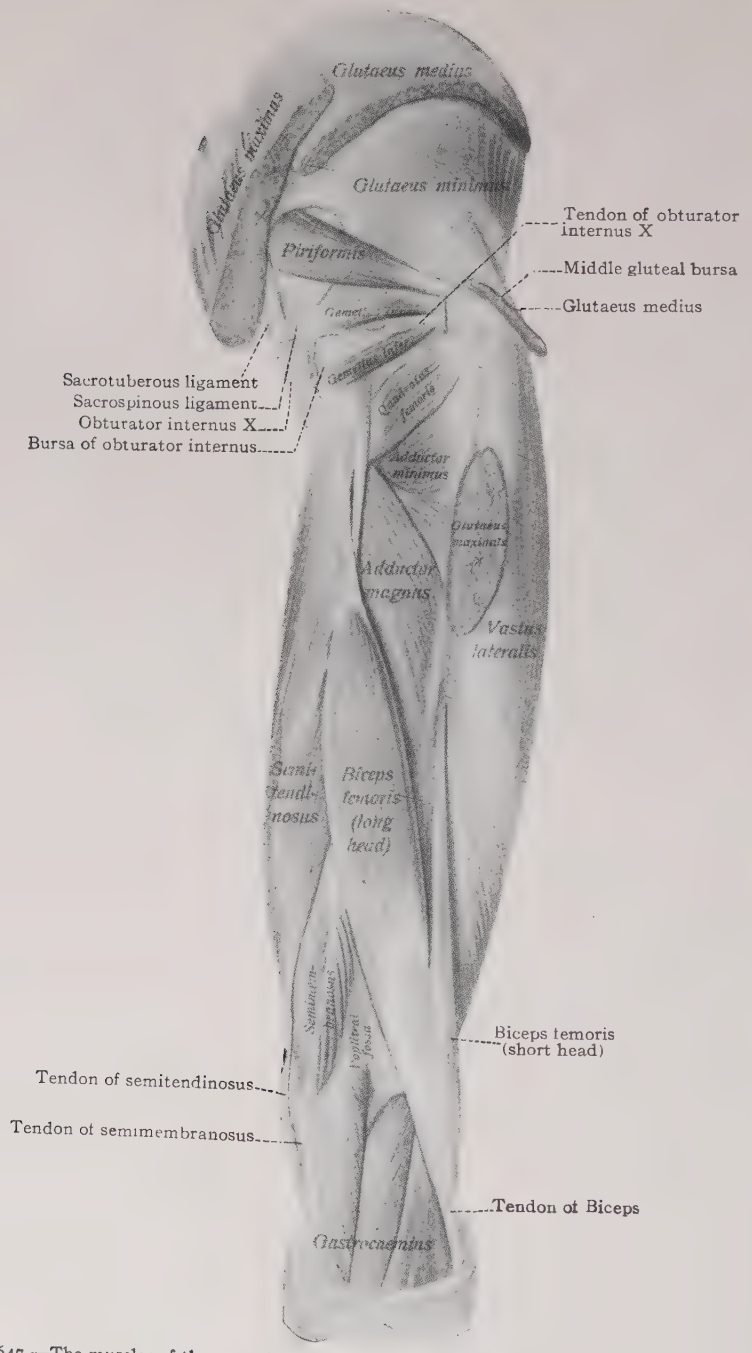


FIG. 647.—The muscles of the posterior surface of the right thigh. (Sabotta: Human Anatomy.)

and forty, or children in the first decade. The incidence in the male sex is far greater than in females, the explanation both as regards age and sex being found in the greater exposure of such persons to trauma.

Displacement.— The factors which determine the type of displacement are the direction of the fracturing force, the level of the fracture, the weight of the limb, and the pull of the attached muscles. Deformity of one or another type is present in almost every case, and may vary from simple angulation, the ends of the fragments remaining in apposition, to complete displacement with over-riding of the bones. Features of deformity almost constantly present are loss of the normal anterior and outward convexity of the shaft and shortening. Also the upper fragment tends to rotate outward through the arc of a circle whose radius is the head and neck of the femur, this being due to the dropping backward of the unsupported trochanter and the influence of the short rotator muscle of the hip.

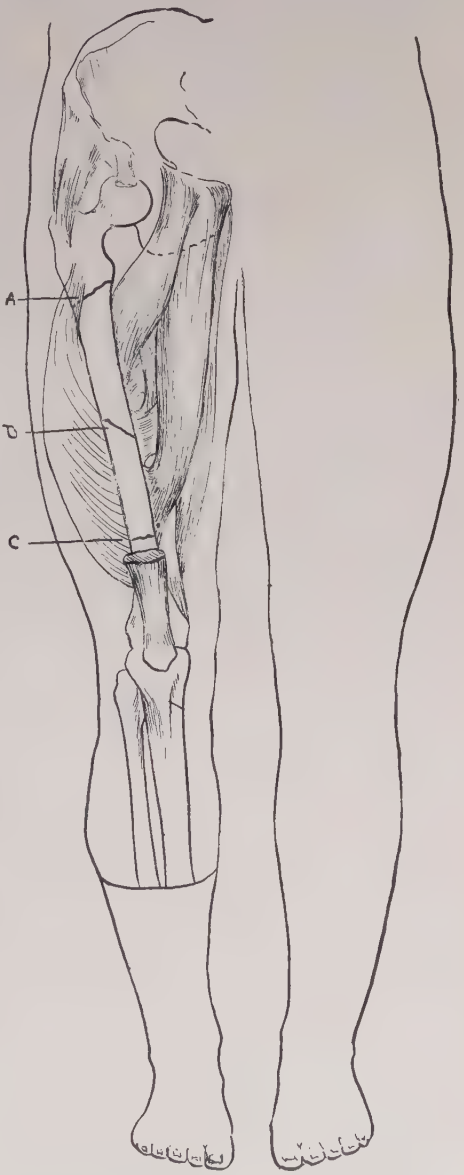


FIG. 648.—Diagram of femur, showing the levels of fracture in relation to muscle attachment. (A) Fracture in upper third. (B) Middle third. (C) Lower third.

Fracture in the Upper Third.— In fractures of the upper third and to a lesser extent, as lower levels are involved, the short proximal fragment is almost constantly flexed due to the action of the iliopsoas muscle, and at the same time it is externally rotated for the reasons stated above (Fig. 649). If the fracture is situated in the subtrochanteric region, the upper fragment is also abducted, due to the loss of the opposing action of the adductor muscles. The longer distal fragment lies posteriorly, riding by the upper fragment and drawn inward by the

adductor muscles. The analysis of the displacement in such cases clearly indicates the method of securing replacement. The shortening must be overcome by traction, and alignment obtained by lifting the distal fragment into proper relation with the proximal fragment. If the upper fragment is flexed, the limb must be placed in the position of flexion. If, in addition, the upper fragment is abducted, the entire limb must be swung out into full abduction, as well as flexed.

FIG. 649.—Fracture of the shaft of the femur, upper third, anterior view. Note the flexion and abduction of the upper fragment.

Fracture in the Middle Third.—When the fracture is situated in the middle third, the various features of the deformity are less constant in tendency, and depend to a considerable extent upon the action of the fracturing force. The obliteration of the normal convexity of the femur is here most constantly shown, and the distal fragment usually lies posterior to the upper fragment (Fig. 651). Outward angulation, when the fragments remain approximated, or inward displacement of the lower fragment when they slip by each other, are frequently present, due to the action of the adductor muscles (Fig. 652). The indications for treatment are well met by powerful traction to overcome the shortening, with lateral pressure and counter-pressure, as indicated, to correct lateral displacement. The seat of fracture should be firmly supported in order to prevent backward sagging of the fragments and to restore as nearly as possible the normal forward bow.

Fracture in the Lower Third.—Fractures in the lower third of the shaft and particularly the supracondylar type of fracture present a very characteristic deformity, the lower fragment almost always being tilted posteriorly from the action of the gastrocnemius muscle (Figs. 653 and 654). The distal end of the upper fragment passes downward and forward toward the patella, and in some cases may make its way into the knee-joint through the suprapatellar bursa (Fig. 656). The main danger from the backward rocking of the lower fragment lies in possible injury to the popliteal vessels (Fig. 655). Compression is more common than actual laceration, but the vitality of the distal segment of the limb may be seriously threatened unless the pressure is relieved by immediate reduction. Less frequently one of the popliteal nerves may be injured. The indications for treatment of these fractures are to overcome the shortening by traction in the long axis of the femur and to correct the

backward rocking of the lower fragment by flexion of the knee to relax the gastrocnemius muscle.

Diagnosis.— Recognition of a fracture of the femur is usually not difficult. The history of the injury, the inability of the patient to use the leg, and the typically shortened and angulated appearance of the thigh all point to the true nature of the condition. Shock is frequently present, of severe type. If seen immediately after injury, before swelling and

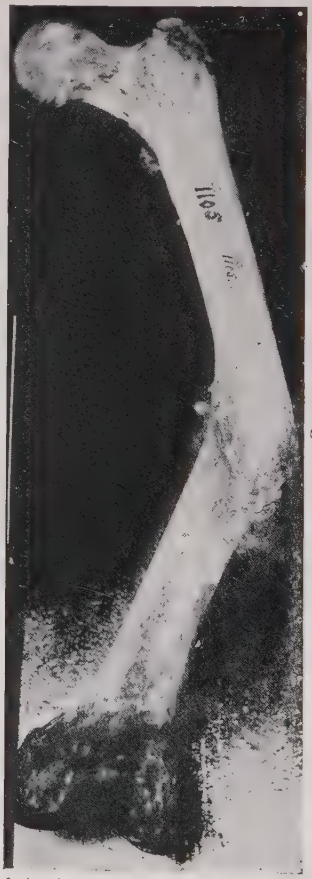
FIG. 650.—Old compound infected subtrochanteric fracture of the femur. (Army Medical Museum.)

spasm have had a chance to obscure the relations, it may be possible to demonstrate the bony deformity by palpation. At a later period it may be difficult to determine the exact level of injury, as the pain of moving the limb or of palpating the bones is excessive, and it is unwise to attempt to elicit crepitus or to demonstrate the seat of the abnormal mobility. The eversion or inversion of the foot are obvious features when present. In the obscure cases the presence of a fracture may be recognized by supporting the back of the thigh with one hand and very gently attempting to move the limb. If the trochanter is fixed with one hand and the leg gently rotated with the other, it will be found that the

latter moves independently of the former (Fig. 657). The demonstration of shortening by measurement of the distance between the anterior superior spine and the internal malleolus is always an important sign of fracture and may vary in amount from 2.5 to 7.5 cm.

Recognition of Nerve and Vessel Lesions.—An essential part of the examination is to test the function of the nerves and the condition of the

651



652

FIGS. 651 and 652.—Fracture of the shaft of the femur, middle third. (651) Specimen illustrating malunion and the characteristic posterior displacement of the distal fragment in fracture at this level. (652) Specimen showing malunion and illustrating the tendency of the adductor muscles to cause outward angulation in fracture at this level. (Warren Anatomical Museum.)

circulation in the lower leg and foot and also to look for injury of the knee-joint. The latter is suggested by the presence of effusion within the articulation and local pain on movement. Inability to voluntarily dorsi-flex the foot or to extend the toes, with loss of sensation on the dorsum, indicate damage to the external popliteal nerve, while loss of power to voluntarily plantar flex the foot or to flex the toes results from injury to the internal popliteal division. In case there is complete involve-

ment of the sciatic nerve, which suggests a lesion in the upper region of the thigh, there is loss of sensation on both the plantar and dorsal surfaces of the foot and complete motor paralysis of the muscles of the lower leg and foot. Interference with the arterial circulation is shown by pallor and coldness of the lower extremity, while pressure on the large veins causes venous congestion, and blueness and mottling of the skin.

FIG. 653.—Fracture of the femur, lower third. Specimen showing malunion and illustrating the characteristic deformity in fracture at this level with posterior tilting of the lower fragment. (Warren Anatomical Museum.)

Roentgen Examination.—Roentgenological examination should be made as a matter of routine in all cases of fracture of the femur, and while unessential from the standpoint of diagnosis, it furnishes information of paramount importance with regard to the treatment. The level of the injury, the variety of the fracture, the extent of the comminution, and the nature of the displacement, as shown by the primary roentgenograms, are all of importance in determining the position in which the limb is to be splinted and how traction is to be obtained. Subsequent examinations should be made at frequent intervals to show the amount of correction obtained and what additional measures are to be employed

to bring the fragments into alignment. To be of value roentgenograms must be made with the patient in his bed and with the apparatus *in situ*, and for this purpose a convenient type of portable roentgen machine is essential. At a still later stage valuable information is to be obtained

FIG. 654.—Fracture of the femur, lower third. Specimen showing the characteristic displacement of the fragments. (Army Medical Museum.)

in respect to the development of callus, the progress of healing, and when to permit weight-bearing. Roentgenograms should always be made in both antero-posterior and lateral planes and should show either the joint above or below the fracture along with the seat of injury. It is easy to form a wrong opinion in regard to the alignment when the roentgenograms are made in only one plane or when they show an inadequate amount of the shaft.

TREATMENT

The treatment of a fractured femur is a difficult problem and one that requires constant attention and unceasing vigilance if a good result is to be obtained and the various complications avoided which make for permanent disability or prolongation of the period of functional incapacity.

Main Objectives.— Of chief concern is the matter of getting the fragments down to full length with the ends in contact and without angulation.

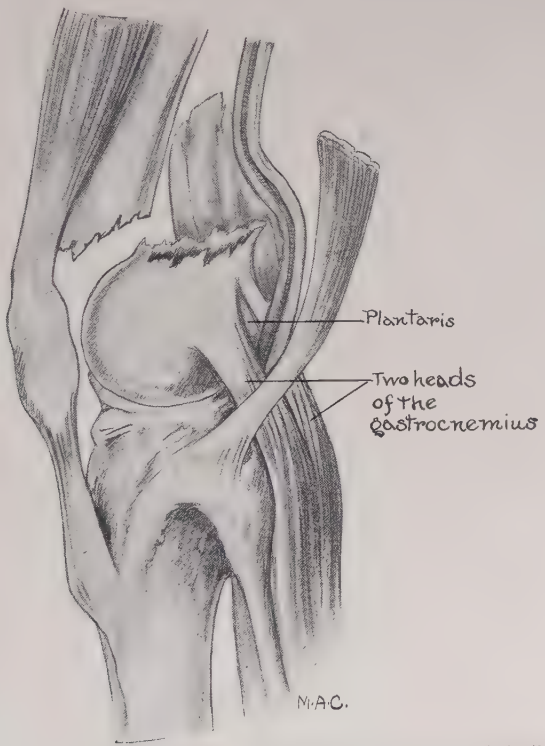


FIG. 655.—Supracondylar fracture of the femur, illustrating the characteristic displacement of the lower fragment and the possibility of injury to the vessels.

Restoration of the normal convexity and correction of rotational displacement are also important. If these requirements can be met, there need be little concern about ultimately obtaining union. Non-union in the case of the femur results almost always from failure to obtain end-to-end approximation of the bones.

Essential Factors in Treatment.— In the very first place it should be stated that the reduction and fixation method of treatment is entirely inadequate in these cases because of the deep situation of the bone, its small diameter, and the displacing influence of the powerful thigh muscles. Heavy, continuous traction must be used to overcome the muscle spasm

and to correct the shortening. External fixation must be employed to immobilize the fragments and hold the limb in the position of relaxation and correct alignment. Both for the sake of comfort and to facilitate the nursing care, provision must be made to allow the patient to

FIG. 656.—Supracondylar fracture with malunion. The specimen shows the characteristic deformity, the condylar portion of the femur lying behind the shaft. The upper fragment has passed down forward into the knee-joint. (Army Medical Museum.)

move about in bed without harm to the seat of fracture. Only by the use of a traction splint of the type devised by Thomas, in conjunction with a system of overhead suspension, is it possible to fulfill all of these requirements.

The Thomas Leg Splint.—The Thomas traction leg splint (Figs. 661-664) is similar in general design and principle to the Thomas arm splint. It is made from ⅜-inch round iron, bent to form a frame consisting of two side-bars and a transverse end-piece, the latter being provided with a v-shaped notch for the attachment of the traction cords. At their proxi-

mal end the side-bars are joined to a metal ring, padded with felt and covered with leather, which is designed to encircle the upper end of the thigh and fit snugly against the tuberosity of the ischium, this serving as the point of counter-pressure for the extension. The ring is placed obliquely on the side-bars and is notched out at the perineum to prevent pressure against the descending ramus of the pubes. As originally used by Thomas, the splint was made individually for each patient, but for general purposes a satisfactory fit may be obtained by keeping on hand two to three sizes of adult splints, large (ring, 75 cm. circumference), medium (ring, 65 cm. circumference), small (ring, 55 cm. circumfer-

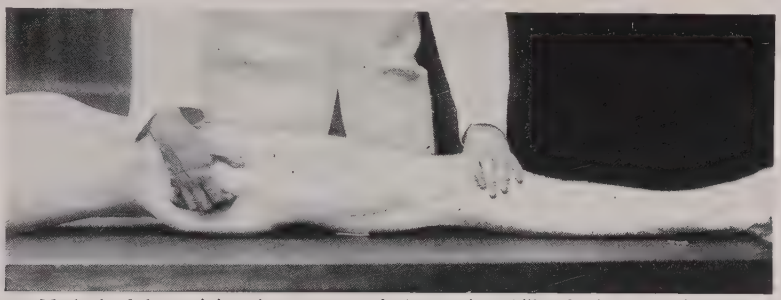


FIG. 657.—Method of determining the presence of abnormal mobility in fracture of the femur. The trochanter fails to accompany the shaft of the femur when the leg is rotated.

ence), and a small, child-sized splint (ring, 40 cm. circumference, and a correspondingly shorter length).

Advantages.—The Thomas traction splint meets the requirements of splinting almost perfectly. It is simple in construction, easily applied, avoids compression of the limb, and enables corrective pressure, by the use of special slings or pressure pads, to be brought to bear in any direction. It allows easy access to wounds, it permits fixation of the limb in the desired position of relaxation, and lastly, it provides the best means of reducing and preventing displacement.

Skin Traction.—Extension may be obtained either by the method of skin traction or skeletal traction. Skin traction is the method commonly used and, if applied with proper attention to details, will be found adequate in the average case of fracture not involving the lower third of the femur. Since they are to sustain a powerful pull, the traction strips, whether of adhesive plaster or of flannel glued to the skin, must be applied to as large a skin area as possible in order that they may remain in place. They should extend from the malleoli to well above the level of fracture in the thigh. Narrow strips of adhesive applied in an ascending spiral fashion should be used to reinforce the main strips. The crest of the tibia should be padded with a strip of cotton or felt and likewise the circular zone immediately above the malleoli in order to protect them from undue pressure. During this entire procedure the leg should be

carefully supported by an assistant who exerts gentle, continuous extension. The limb should then be firmly and evenly bandaged. The use of a compression bandage is of considerable importance in solidly fixing the traction strips, and it should be reapplied as often as necessary to

FIG. 658.—Supracondylar fracture in a child. (Fracture Service, M. G. H.)

keep it tight. Under ordinary circumstances extension strips which are applied in this manner may be depended upon to hold for about four weeks, when they must be reapplied.

Application of the Splint.—A Thomas splint of proper size is now applied, the ring being passed over the foot and pushed upward until it rests against the tuberosity of the ischium. The supporting bands, which are of canton flannel material (10 to 12 cm. wide), are then adjusted, being fixed to the side-bars with safety pins or broad paper clips. The first, or "master band," spans the side-bars at the level of the fracture and should be pulled tight (Figs. 665-668). The limb is then lowered

upon this band, the effect being to restore the normal forward curve of the shaft, and the traction cords or straps are tied to the notch in the end of the splint. In order to avoid pressure on the ankle and also to hold

FIG. 659.—Fracture of the femur in a child, fourteen years. Before reduction. (Fracture Service, M. G. H.)

the limb in the position of slight external rotation, the cords should be crossed over the side-bars in a special manner before being attached. The outer extension cord should pass under and then over the outer bar, while the inner cord should pass over and then under the inner bar. Additional

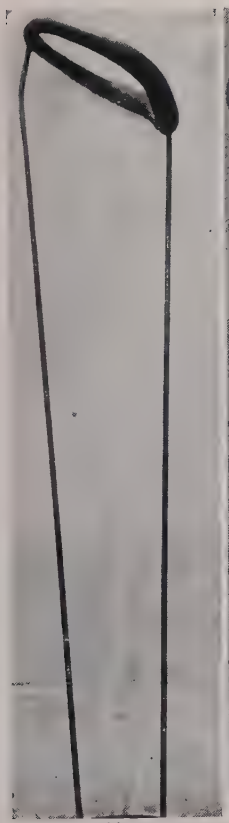
extension is obtained by inserting a stick or nail between the cords and twisting them to the desired amount of tension.

The rest of the flannel slings are then fixed in place, enough bands being used to form a perfect gutter for the limb, extending from the

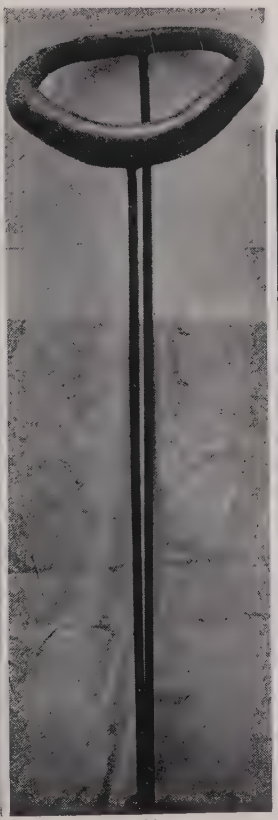
FIG. 660.—Fracture of the femur in a child, fourteen years. After reduction. Large amount of callus. (Fracture Service, M. G. H.)

ankle to the upper end of the splint. Care should be used to place them close together so that no space is left through which the soft parts of the thigh may protrude. The slings in immediate proximity to the master band should not be applied so tightly that they remove the supporting effect of the former. The femur should be kept at the level of the side-bars of the splint.

Suspension of the Splint.—The splint having been applied, its suspension is next in order, and for this purpose an overhead frame of suitable type should be erected over the bed. Many methods of suspension are in use, some of them very complex, but simplicity is desirable, and we have

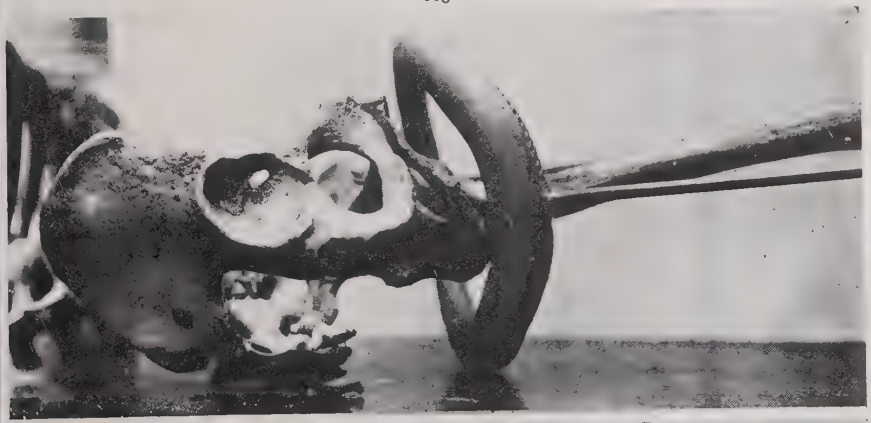


661



662

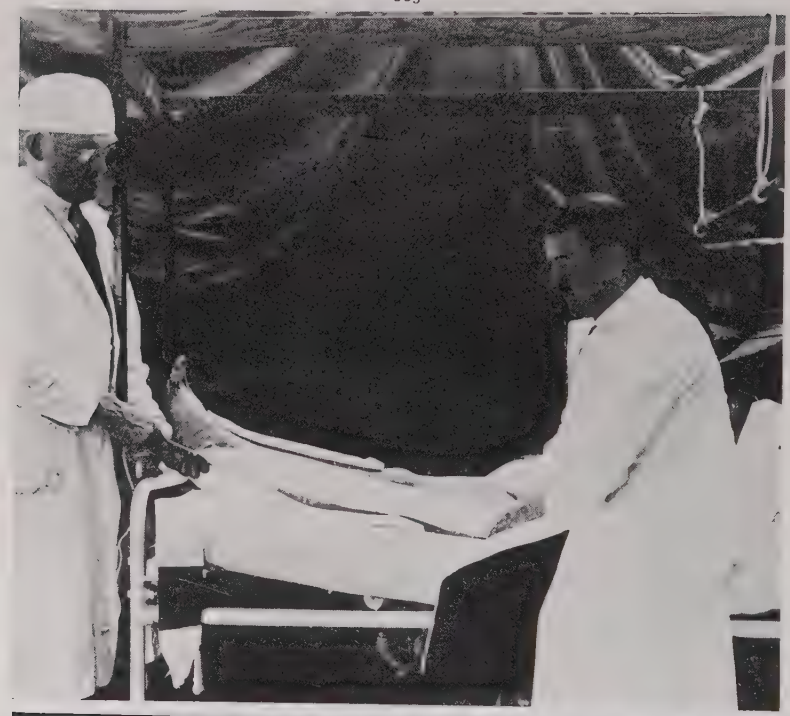
663

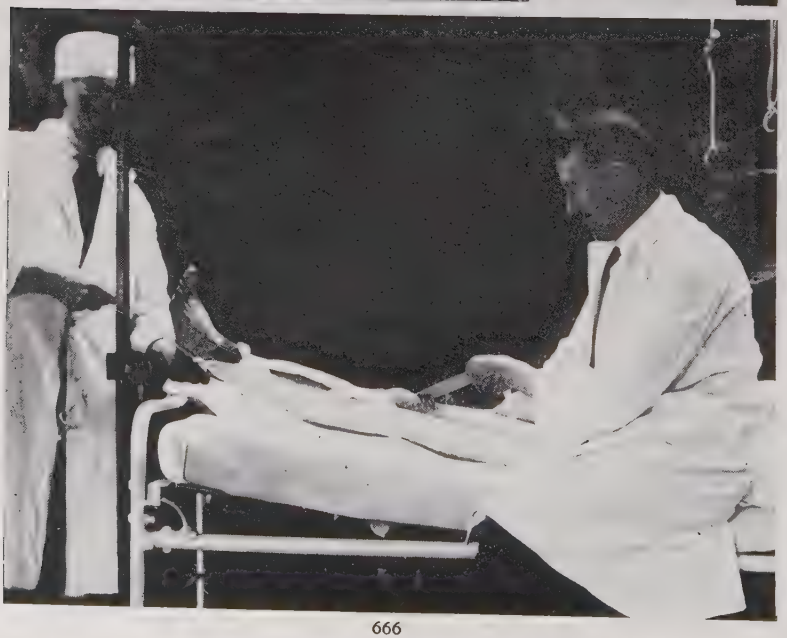


664

FIGS. 661, 662, 663 and 664.—The Thomas splint. (661) Anterior view. (662) Mesial view. Note the notched depression in the ring on the mesial side, this being necessary to prevent painful pressure on the perineum. (663) Illustrating how counter-pressure is obtained from contact of the ring with tuberosity of the ischium. (664) The splint in relation to the skeleton. Note the anterior bow of the femur.

665





666

667

668

FIGS. 665, 666, 667 and 668.—Application of the Thomas splint. (665) Traction strips are applied to the mesial and lateral aspects of the leg. The edges of the adhesive should be nicked with the scissors to allow smooth conformation to the skin surfaces. The crest of the tibia should be protected with cotton padding. (666) Additional fixation is secured by the application of crossed spiral adhesive strips. (667) A firm circular bandage is applied over all. Manual traction should be exerted and the fracture supported by assistants during the entire procedure. (668) The splint is threaded over the leg and the master band tightened.

found Pearson's [1] system very effective. The end of the splint is fastened to the foot of the bed or to the end piece of the frame in such a manner as to lift it 25 to 35 cm. above the level of the mattress (Fig. 670).

[1] Pearson and J. Drummond, "Fractured Femurs; Their Treatment by Caliper Extension." *Oxford University Publications,* London, 1919.

The ring is then suspended by means of a cord passing vertically upward to an overhead pulley and from there to a second pulley at the head of the bed, where it is attached to a counterpoise weight of five to ten pounds (Fig. 671). A hand grip should also be suspended from the frame at a convenient height to allow the patient to utilize his arms as an aid to movement. By elevating the pelvis with the uninjured leg and pulling the trunk upward with the hands, the entire body may be raised from the bed, which permits proper care of the back and the use of the bedpan without difficulty (Figs. 675, 676). A considerable range of movement in bed is also possible, the body moving in the arc of a circle, the centre of which is represented by the point of attachment of the splint to the bed, the radius being the splint itself.

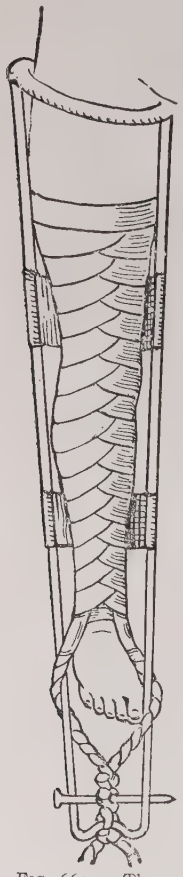


Fig. 669. — Thomas splint applied. Traction secured by knotting the traction cords to the end of the splint and twisting them with a nail or a small piece of wood. (Fixed type of traction.)

Suspension in this manner not only promotes the comfort of the patient but also benefits the general condition by permitting a considerable amount of exercise. It also counteracts the tendency for the ring of the splint to be displaced upward against the perineum under the influence of the heavy extension force. The vertical overhead pull causes the ring to hug the posterior surface of the thigh below the tuberosity and to remain in place even when the pelvis is raised from the bed.

Fixed and Sliding Type of Traction.—Traction is of the fixed type (Fig. 672) when it is obtained by tying the cords to the end of the splint and twisting them as previously described (p. 535). The fixed type of traction is very effective, but daily adjustment is necessary to maintain the proper tension. Also, the amount of extension is immediately lessened if the ring becomes displaced with reference to the ischial tuberosity, and there is corresponding loss of position. To prevent this a splint with a close-fitting ring should be employed, but this presents considerable disadvantage, since the position of flexion of the hip, which is frequently necessary to bring about muscle relaxation and alignment, causes the front of the ring to impinge against the anterior superior iliac spine with resulting pain and pressure. On the other hand, with the sliding type of traction (Fig. 673), the tension remains unvaryingly the same under all circumstances, and there is, therefore, no danger in using a large size ring, but rather every advantage because of the greater comfort and freedom of movement which it permits.

Elevation of the Foot of the Bed.—In order to completely overcome the shortening it may be necessary to employ a very strong traction force,

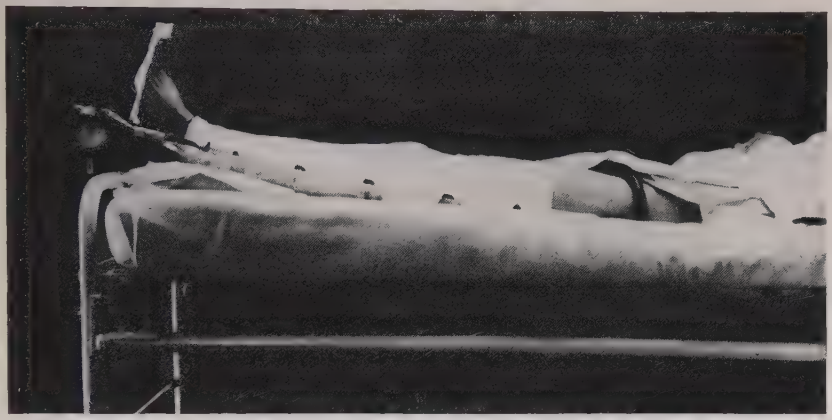


FIG. 670.—Thomas splint applied. The end is fastened to the crossbar of the frame, and the foot may be supported by the metal right-angular foot-support.

the equivalent of 50 to 60 lbs. being at times required, but usually only for short periods. Under such circumstances the counter-pressure of the

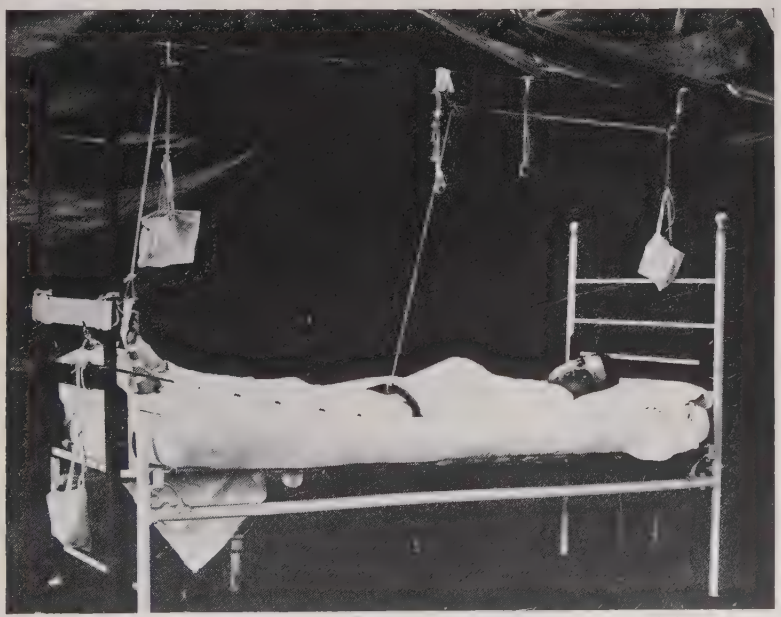


FIG. 671.—Suspension of the splint. The ring is suspended from the overhead frame and counterpoised with weight. The foot may be supported by fixing an adhesive strip to the plantar surface which is connected with a cord running to an overhead pulley and fastened to a weight.

ring against the tuberosity of the ischium becomes quite painful and may even threaten the formation of pressure sores. Very marked relief may

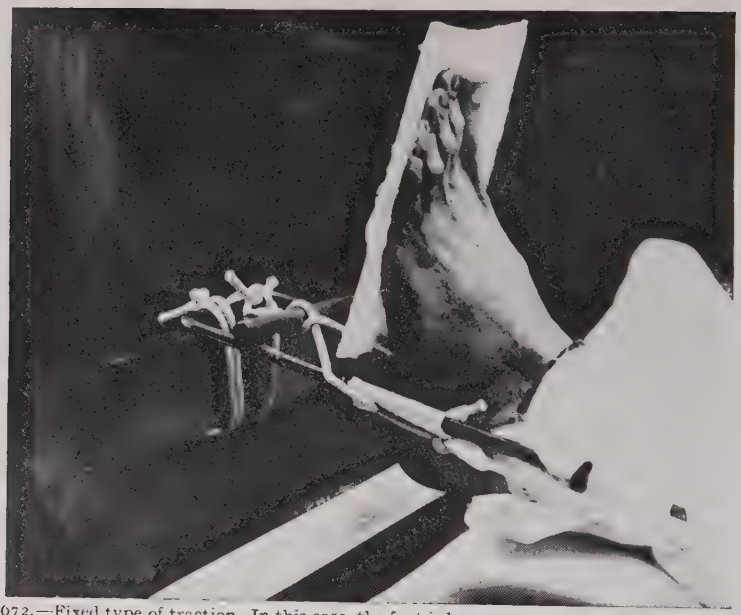


FIG. 672.—Fixed type of traction. In this case, the foot is being supported by the metal foot-piece.

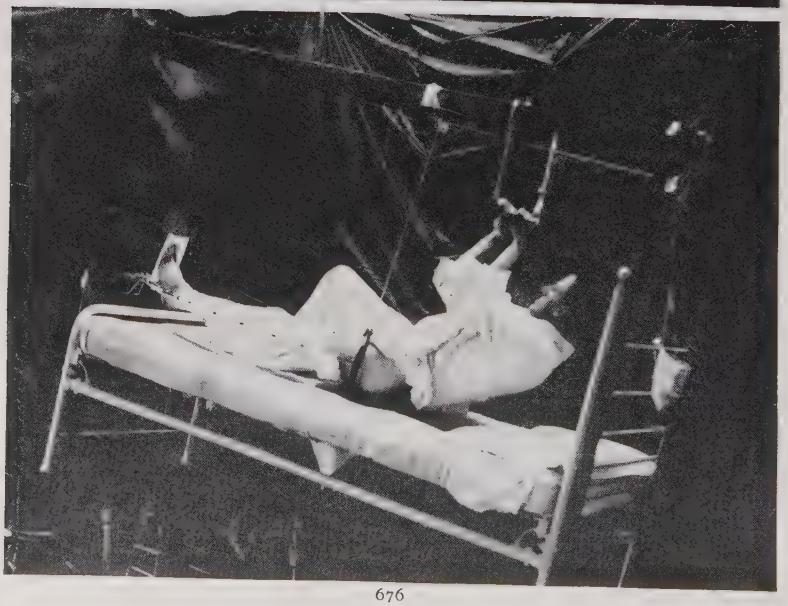
FIG. 673.—Sliding type of traction. In this case, the foot is being supported by an adhesive band which in turn is suspended from an overhead pulley and counterpoised with a small weight.

be obtained by elevating the foot of the bed a distance of 30 to 45 cm. The pillows should be entirely removed, and the patient made to remain flat, and in this position the weight of the body itself provides counter-traction and tends to pull the tuberosity away from the ring so that the pressure is eased. With the fixed type of traction this is quite an impor-

FIG. 674.—Suspension of the splint. When heavy extension is required to obtain alignment, undue pressure may be exerted by the ring against the tuberosity of the ischium. In this case relief is to be obtained by elevating the foot of the bed, thus utilizing the weight of the body for counter-traction.

tant step in the procedure, as it prevents upward displacement of the splint, and the downward drag of the body weight adds materially to the force of the extension. With the sliding type of traction the position does not increase the amount of the extension, but it does add to the comfort. At the same time it is necessary to employ enough traction weight to prevent the patient from sliding downward out of the splint. The opposition of the friction of the body and the bedclothes is considerable, and, if the weight used is in excess of 30 to 35 lbs., there is little tendency for this to occur. The authors are in the habit of elevating the foot of the bed as a matter of routine when the fixed type of traction is used, but with the sliding type of traction this is done only when a very heavy extension weight is employed and there is likely to be complaint from the pressure of the ring.

675



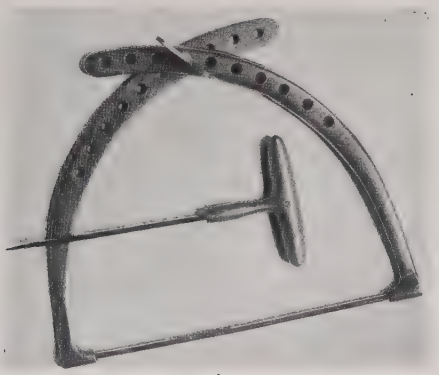
676

FIGS. 675 and 676.—Suspension of the splint. (675) The splint suspended and the foot of the bed elevated. (676) With proper suspension of the splint, the patient may lift his body and change position without altering the alignment of the fragments.

Support of the Foot.—The foot must be supported at right-angle flexion in order to prevent it from assuming the position of equinus, a deformity which quickly becomes permanent from shortening of the

677

678



679

FIGS. 677, 678 and 679.—(677) Bone calipers or "ice tongs," Adams type, used at the Massachusetts General Hospital. (678) Pearson's calipers. (679) Steinmann pin and stirrup. A removable handle, as shown, is supplied to drive the pin through the bone. The pin is jointed at the middle and the halves may be unscrewed and removed from the wound separately.

tendo Achillis, and which later gives rise to very great difficulty when weight-bearing is attempted. The right-angle position may be obtained by the use of a small rectangular foot attachment made of heavy iron wire, which fits on the side-bars of the splint (Fig. 672). When covered with bandage this provides a firm support for the foot. A better method, because it allows free movement at the ankle, is to apply a strip of adhesive plaster to the sole of the foot (Fig. 673) and connect this by

means of a cord and overhead pulley to a small weight (one to two pounds). Still another method is to suspend the foot by a strip of adhesive plaster to the top of the wire foot support.

SKELETAL TRACTION

Calipers or Ice Tongs.—The method of obtaining extension by the application of a metal instrument directly to the bone is a comparatively

680

681

FIGS. 680 and 681.—Lateral and anterior views of a dissected knee-joint, illustrating the proper point for the insertion of a Steinmann pin or the application of ice tongs in obtaining direct skeletal traction on the femur. Note its relation to the capsule of the knee-joint.

modern innovation, but one that has already demonstrated its real usefulness and general lack of danger when used under proper hospital conditions. The original method consisted of passing a nail or pin through the lower end of the femur, the traction force being connected with the protruding ends of the pin. Steinmann's pin has now been largely superseded in general use by the calipers, or ice tongs, which grasp, but do not penetrate, the bone, and thus expose the patient to less danger in case of

infection. Many modifications of Ransohoff's or Beasley's original instruments are now available, each possessing some special point of merit, but for general all-around use we have found calipers of the Pearson or Adams type perfectly satisfactory (Figs. 677-679).

Anæsthesia.—The actual application of the calipers is a simple mat-

682

683

FIGS. 682 and 683.—Skeletal traction. Roentgenograms showing the points of the calipers in position. (682) Adult femur. No penetration of the bone. (683) Same in the case of a child, showing close proximity of the points to the epiphyseal junction. In this case, because of the softness of the bone, there has been slight penetration of the points.

ter occupying only two to three minutes, and the operation is best performed under nitrous oxide anæsthesia, or, if this is not desirable, local anæsthesia by means of novocaine may be employed. The success of the whole procedure depends upon everything being in readiness so that immediately following their insertion the calipers may be connected with the extension weight, the splint suspended, and the entire splint system perma-

nently adjusted. For this reason the operation should be performed in the patient's room, with the patient in his bed, over which an overhead suspension frame has previously been erected.

Preparation of the Splint.— The splint should be threaded over the leg, the ring suspended (see page 536), and the end of the splint fastened to a

FIG. 684.—The hinged knee attachment for the Thomas splint. The screw clamps enable it to be fixed to the splint at the level corresponding to the centre of knee motion and any desired amount of flexion may be obtained.

crossbar on the end of the frame, which is elevated 75 cm. to 90 cm. above the level of the mattress. Since this position involves a considerable degree of flexion of the hip, it is essential that a splint be selected with a large ring so that pressure upon the anterior superior iliac spine may be avoided. The supporting bands of flannel should be fixed to the side-bars

under the region of the thigh, the same care being used in adjusting the master band as when skin traction is to be employed, but no slings should be placed below the level of the knee.

Hinged Leg Support.—Skeletal traction in the case of fracture of the femur is used to the best advantage in conjunction with Pearson's hinged leg attachment for the Thomas splint (Fig. 684). This is a short, rectangular, iron frame similar in shape to the lower half of the Thomas splint, but provided at the upper end with hinged joints and clamps. By

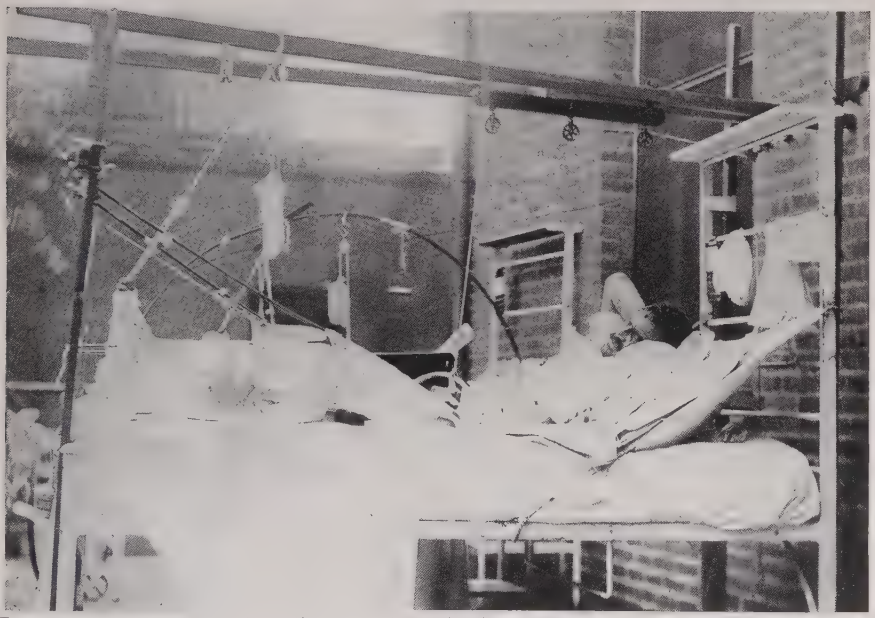


FIG. 685.—Photograph showing splint suspended and calipers in position. (Fracture Service, M. G. H.)

means of these clamps it is fastened to the side-bars of the main splint, great care being employed to centre the hinged joints on a line corresponding with the centre of movement of the knee-joint. It is converted into a trough to support the leg by spanning its side-bars with supporting bands of flannel, as in the case of the main splint. By means of this movable attachment any desired degree of knee-flexion may be obtained, and at a later stage mobilization of the knee-joint may be permitted.

Application of the Calipers.— With everything now in readiness one may proceed with the actual insertion of the calipers. Rigid asepsis must be observed as in the case of any other operation. The skin in the region of the knee and lower half of the thigh, which has previously been shaved, is now cleansed with benzine and ether and painted with tincture of iodine. Sterile towels are inserted between the posterior surface of the thigh and splint and above and below the operative field, and the sterile table

bearing the instruments is placed conveniently at hand. With the gloved fingers of the left hand, the operator draws the skin upward in the region of the condyles, and with the right hand locates the adductor tubercle on the inner side of the thigh slightly above the knee. The anæsthetic is

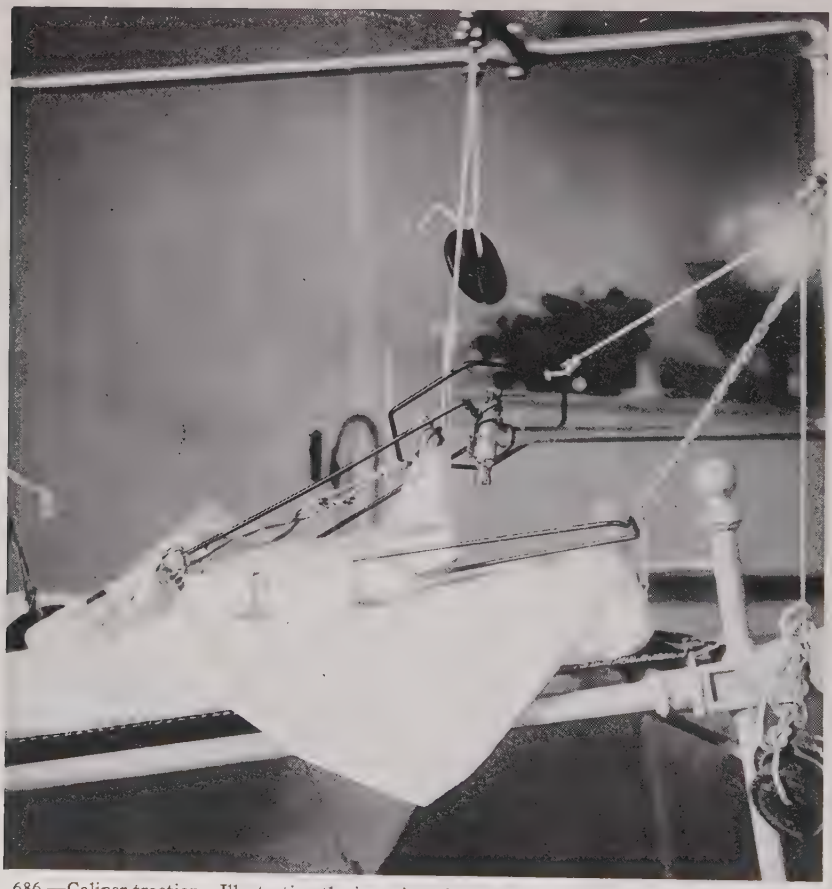


FIG. 686.—Caliper traction. Illustrating the insertion of a metal ring in the extension cord to avoid pressure by the latter upon the foot

now administered, and as soon as the patient is unconscious the operator makes two incisions in the longitudinal axis of the limb, each about one inch long, the inner one being placed just above the adductor tubercle and the outer one at a corresponding point on the lateral aspect of the femur. Clean, deep cuts should be made penetrating to the bone, the upward retraction of the skin being maintained with the left hand. The points of the calipers are then inserted and tapped into position, the effort being made to place them on a transverse plane passing 1.25 cm. above and anterior to the adductor tubercle. The skin pressure is then released and

the handles of the calipers compressed and locked in position by the lock nut (Adams' calipers). Sterile sponges wet in alcohol are wrapped around the penetrating portions of the calipers, and an abundant dressing is used to cover the incisions. The handles of the calipers are connected by means of a cord with the extension weight and the traction force immediately applied. The hinged leg support is suspended from the main

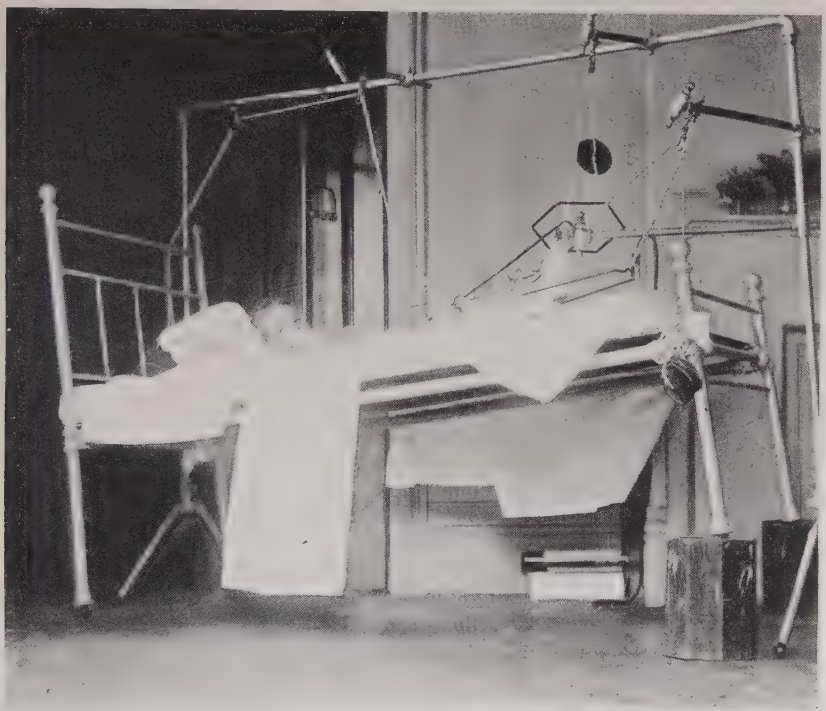


FIG. 687.—Caliper traction. Showing general method of suspension of splint. (Morrison's demountable overhead frame.)

splint by means of a cord at the desired angle of flexion, and the foot is supported in the right-angle position as previously described (p. 545).

Dangers.—There has been a feeling of hesitation among a great many surgeons in regard to the use of skeletal traction, but experience has been accumulating, and while the method is not entirely free from danger, the risk is exceedingly small when used under hospital conditions, certainly much less than with most other surgical procedures. Infection is a rare complication with proper technic. The dressings need not be changed except at long intervals unless specific indications for inspecting the wound arise. At such times considerable purulent material may be found about the caliper points, but in a large number of cases this yields negative cultures. The patient complains of pain only when the calipers exert

688

689

FIGS. 688 and 689.—Caliper traction. Method of supporting the leg when the hinged splint attachment is not available. (688) The leg is suspended, with the knee flexed, by means of long slings of webbing or muslin. (689) View of the suspended splint.

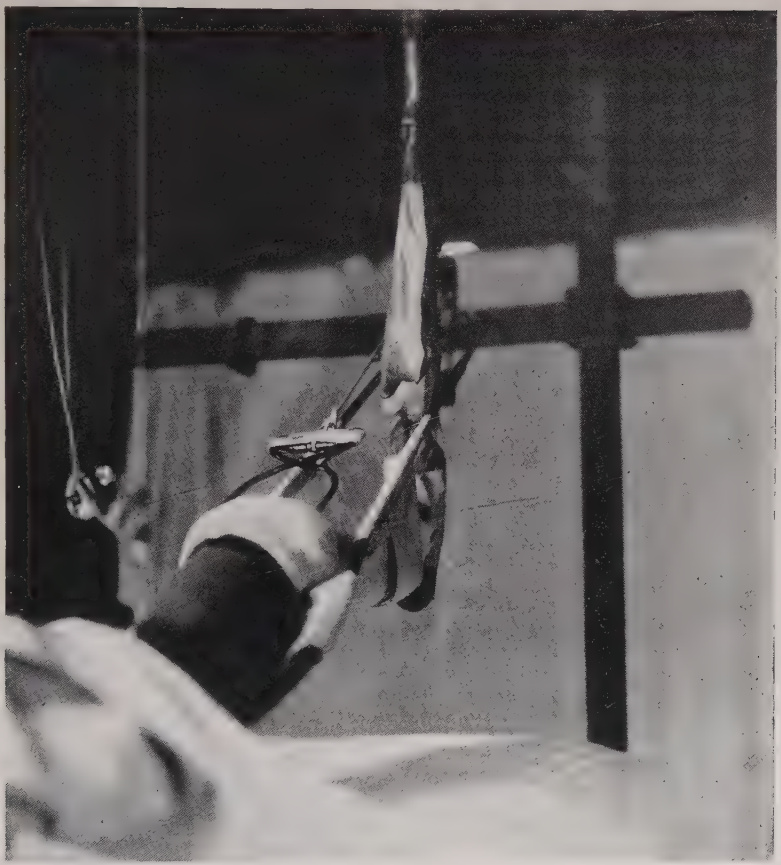


FIG. 690.—Caliper traction. View of the splinted leg from above, showing the calipers in position.

pressure on the edge of the skin, and with care at the time of their application this may be avoided. Another danger is that the force of the extension, by tending to compress the handles of the calipers, may cause the points to penetrate deeper and deeper into the bone. To avoid this, no caliper should be used which is not provided with a lock nut to hold the handles separated at any given distance. Slipping of the calipers has occurred; in one case known to the authors, causing injury to the external popliteal nerve. This may be avoided by proper application of the calipers above the expanded lower extremity of the femur and daily care to see that the right amount of tension is maintained. Opening of the knee-joint with subsequent infection may occur if the calipers are applied at too low a level (Figs. 680, 681). The calipers should usually be removed at the end of six weeks on account of the increasing risk of infection. By this time the fragments are well united and the alignment may be maintained

by light adhesive traction to the thigh, the same splint being used (Fig. 712).

Advantages.—On the other hand, caliper extension presents certain very definite advantages. The traction force is applied directly to the bone

691 692

FIGS. 691 and 692.—Improper use of calipers in fracture of the lower third of the femur. (691) Lateral view. The points have been inserted too far anteriorly and an excessive amount of traction is being used. The original deformity has been over-corrected and there is now a reverse deformity which is equally bad. (692) Same case, antero-posterior view, showing separation of the fragments from an excessive amount of traction. (Fracture Service, M. G. H.)

where its effect is desired, and since there is no diffusion or loss of force a smaller amount of extension weight is required than with skin traction. It also remains in place better than skin-extension, which is subject to the danger of slipping or of causing blistering of the skin. It permits a position of flexion of the knee, which in fractures of the lower third of the femur is necessary in order to relax the gastrocnemius, and, if applied eccentrically in such cases,—that is, with the points anterior to the axis of

the shaft of the femur,—the pull is exerted in such a way as to rotate the lower fragment forward and correct the deformity. It also permits early mobilization of the knee-joint, a certain amount of movement of the leg in the hinged support not being inimical to healing, provided that

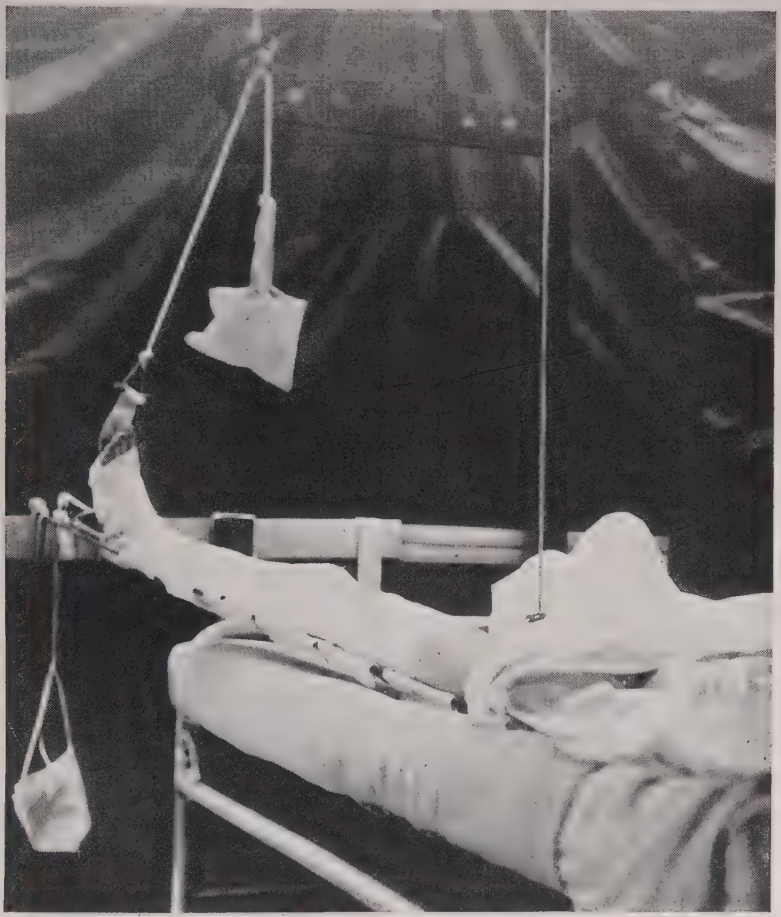


FIG. 693.—Fracture of the femur, upper third. Note that the leg is swung out into abduction by the application of an abduction arm to the end of the frame.

the knee hinges are accurately centred so that the movement takes place at the knee-joint and not at the seat of fracture. In this way much may be done to prevent stiffness of the knee, a frequent and disabling result of fractured femur. A further advantage lies in the complete exposure of the thigh for the purpose of massage, which may be begun immediately. In compound fractures this is a very positive and desirable advantage, as complete exposure of the wound is obtained for purposes of treatment without in any way impairing the position of the bones or their immobilization.

TREATMENT OF FRACTURES OF THE FEMUR AT DIFFERENT LEVELS

Fracture in the Upper Third.—When the fracture is situated in the upper third, it is necessary in order to secure alignment to swing the leg out into a position of wide abduction with flexion of the hip of about 40° and

FIG. 694.—Fracture of the femur, upper third, treated by skin-extension. Lateral view. Note the position of flexion and abduction. A pressure pad may be seen in position on the side of the splint. (Fracture Service, M. G. H.)

moderate, external rotation. The end of the Thomas splint should be fastened to an extension board projecting laterally from the end of the frame and so arranged as to permit the necessary amount of abduction and flexion (Figs. 693-695). External rotation of the desired amount is obtained by twisting the traction cords about the side bars of the splint in such a way as to cause the limb to roll outward to a moderate extent. Adhesive skin traction is usually adequate to correct the deformity in such cases, but skeletal traction may be used with advantage in powerfully-muscled patients, particularly when the fracture is of the difficult subtrochanteric variety.

Fracture in the Middle Third.— In fractures of the middle third the one fairly constant feature of deformity is posterior displacement of the distal fragment. In such cases skin traction usually meets the needs and it is

sufficient to use a straight Thomas splint, the end being elevated 25 to 30 cm. above the mattress. When the distal fragment is also displaced mesially, as occurs in a considerable number of cases, it may be necessary to exert lateral pressure and counter-pressure upon the respective frag-

FIG. 695. -Fracture of the femur, upper third, treated by skin-extension. End view. Note the position of flexion and abduction. (Fracture Service, M. G. H.)

ments either by means of screw pressure pads (Figs. 700, 701) or by flannel slings encircling the thigh above and below the seat of fracture and fastened to the side-bars of the splint. With this variety of injury the normal forward curve of the femur is practically always obliterated, and special attention should be paid to the proper adjustment of the "master band," which has the duty of restoring it.

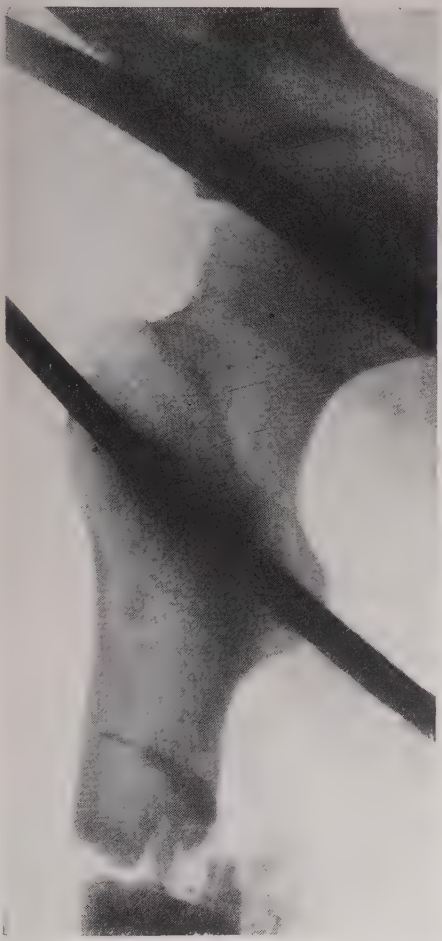
Fracture in the Lower Third.—In fractures involving the lower third of the femoral shaft the deformity is almost constantly one of backward tilting of the lower fragment with over-riding. In order to secure align-

696 697

FIGS. 696 and 697.—Fracture of femur, upper third. Roentgenograms showing original deformity. Note abduction and flexion of upper fragment. (696) Antero-posterior view. (697) Lateral view. (Fracture Service, M. G. H.)

ment it is necessary to relax the gastrocnemius by flexing the knee, at the same time exerting traction on the lower fragment in the long axis of the femur. When the deformity is slight, it may be possible to obtain correction by bending the side-bars of the splint at the level of the knee to an angle of 160°, supporting the lower fragment with a very firm flannel band, applying adhesive skin traction to the lower leg, and employing strong extension of the fixed type (Fig. 702). When the deformity is considerable, however, as is the case with the average fracture in this

situation, caliper extension offers the most effective means of correction (see p. 546). (Figs. 686, 687.) Care should be exercised with this method not to employ too strong a traction force, as this may cause over-



698

699

FIGS. 698 and 699. (Same case shown in Figs. 696, 697.)—Fracture of femur, upper third, treated by skeletal traction (calipers) in Thomas splint. Roentgenograms taken several weeks later, showing complete correction. (698) Antero-posterior view. (699) Lateral view. (Fracture Service, M. G. H.)

correction of the displacement, with the production of a reverse deformity (Figs. 691, 692).

Supracondylar Fracture.—With the supracondylar type of fracture, in which the injury is situated just above the condyles, the proximity of the fracture line to the point where the calipers are usually applied renders their use unsafe, as it involves the risk of converting a simple fracture into one that is compound. The same applies to an extensively comminuted fracture of the lower third of the shaft. The supracondylar fracture is

usually of a transverse type and this lends itself to the reduction and fixation method of treatment, the situation of the bones being fairly superficial and their diameter wide enough to offer hope of retention in case reduction is accomplished. Reduction is obtained by manipulation under an anæsthetic, the knee being flexed and traction exerted on the bent

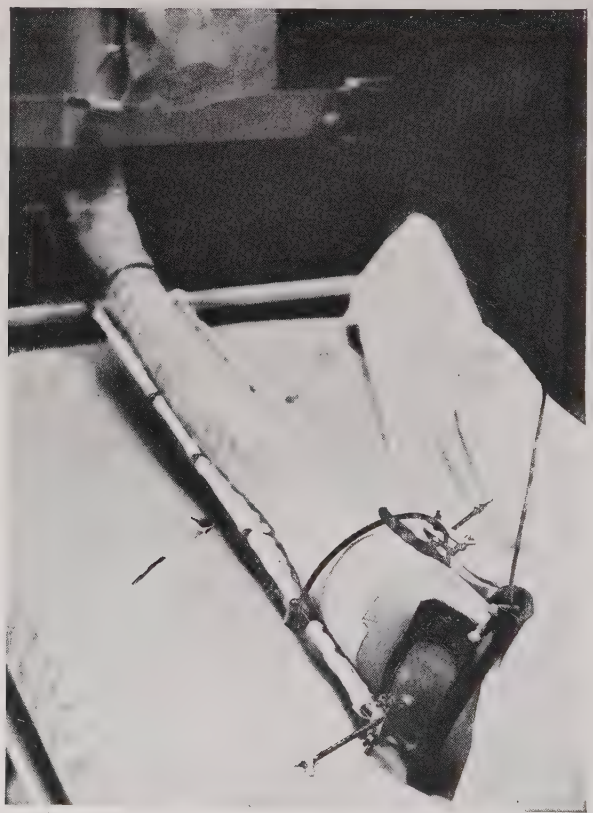


FIG. 700.—Correction of lateral displacement by the application of screw pressure pads, which exert appropriate pressure upon the upper and lower fragments. Fracture of the femur, middle third. Pressure pads in position.

knee. The fragments should be retained in position by the application of a plaster of Paris spica casing, which includes the entire limb and pelvis, the knee being flexed to a right angle.

Skeletal Traction to the Upper End of the Tibia.—When the reduction and fixation method is not applicable a jointed Steinmann pin (Fig. 679) may be passed through the crest of the tibia just below the tibial tubercle, and skeletal traction employed. The adjustment of the traction, the application of the splint, and the method of suspension are similar in all respects to those previously described in connection with caliper extension (Fig. 740).

AFTER-TREATMENT OF FRACTURES OF THE FEMUR

Gradual Correction of Deformity.— So far as the fracture itself is concerned immediate correction of the deformity is not to be expected. The

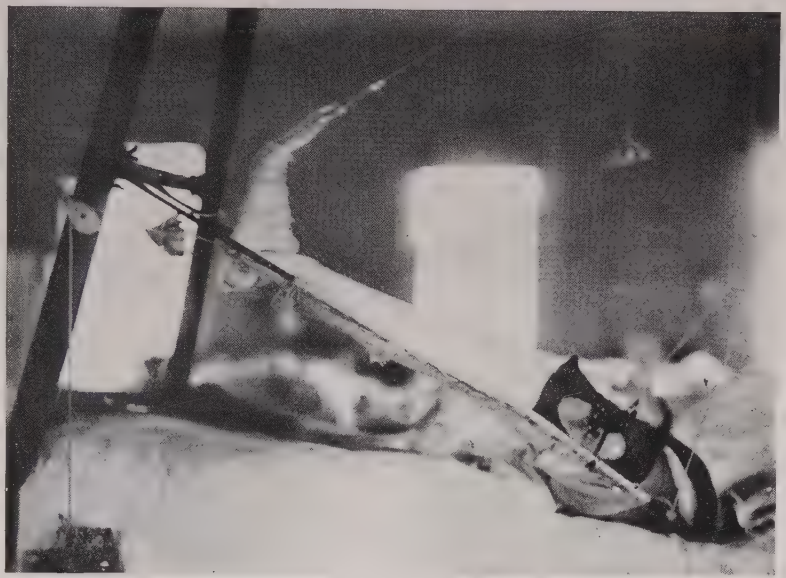


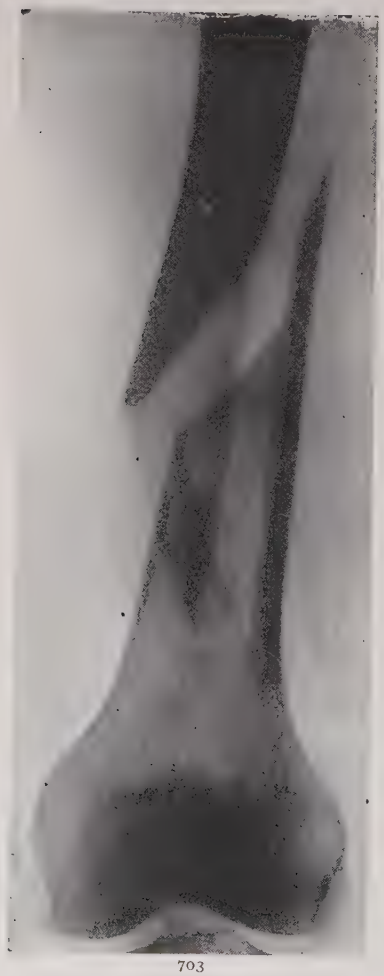
FIG. 701.—Correction of lateral displacement by the application of screw pressure pads, which exert appropriate pressure upon the upper and lower fragments. Fracture of the femur, middle third.

whole plan of treatment is based upon the idea of placing the fragments under effective control and then by gradual steps bringing them into align-

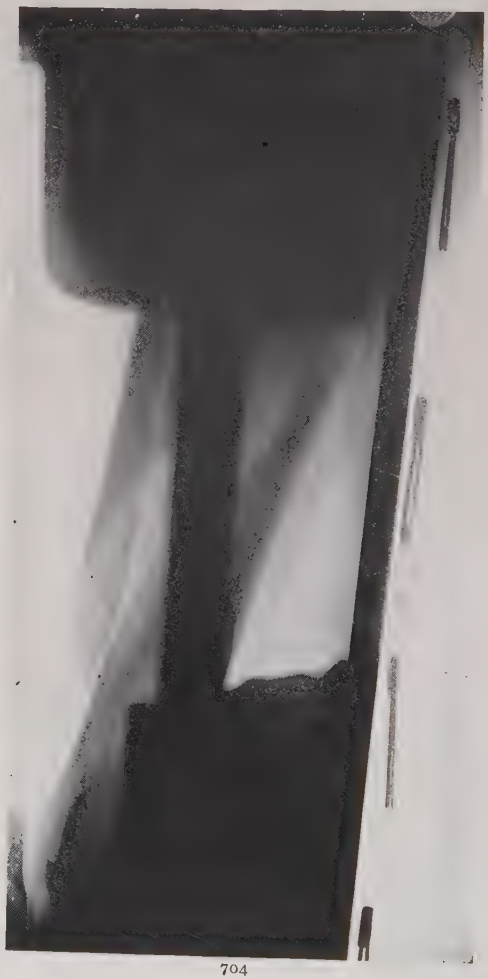
FIG. 702.—Fracture of the femur, lower third, showing the application of the bent Thomas splint with skin-extension. Knee-flexion is required to overcome the backward tilting of the lower fragment. (Fracture Service, M. G. H.)

ment. Improvement of position is to be obtained by minor adjustments of the apparatus as indicated from time to time by the Roentgen examination.

Correction of Shortening.—Correction of shortening is the first objective, and only when this has been accomplished is the reduction of lateral displacement to be attempted. The former is to be obtained by increasing the force of the extension until the limb has been drawn out to full length



703



704

FIGS. 703 and 704.—Spiral fracture of the femur, following application of extension in Thomas splint. Satisfactory position obtained by skin traction alone. (703) Anterior view. (704) Lateral view. (Fracture Service, M. G. H.)

as determined by comparative measurements of the distance between the anterior superior spine and the internal malleolus, or, in case the knee is flexed, the distance between the anterior superior spine and the upper border of the patella. The initial force required varies from 12 to 20 kilos with the method of skin traction, and 10 to 15 kilos with the

method of skeletal traction. When full length has been obtained, the weight may be reduced.

Correction of Lateral Displacement.—Lateral displacement is only to be corrected when the full effect of the extension has been first obtained.

FIG. 705.—Fracture of the femur at junction of lower and middle thirds, showing typical deformity. Lateral roentgenogram. (Fracture Service, M. G. H.)

At this time screw pressure pads may be adjusted on the side-bars of the splint (Figs. 700, 701) to exert the proper kind of pressure and counter-pressure on the respective fragments, or lateral traction by means of flannel bands encircling the thigh may be applied. Displacement in the antero-posterior plane is chiefly to be overcome by flexion of the hip and knee to relax the muscles responsible for the deformity. In special instances transverse metal arches may be adjusted to the side-bars of the splint, by

FIG. 706.— Fracture of the femur at junction of lower and middle thirds, showing typical deformity. Antero-posterior roentgenogram. (Fracture Service, M. G. H.)

means of which the screw pressure pads may be brought to bear in the antero-posterior direction. These measures are not often necessary.

Daily Adjustment.—Special emphasis should be placed upon the neces-

707 708

FIGS. 707 and 708.—Fracture of the femur. Reduction by the application of direct skeletal traction with "ice tongs." (707) Before reduction. (708) Following reduction, anterior view. (Fracture Service, M. G. H.)

sity of daily inspection and adjustment of the apparatus. The supporting bands must be kept tight, the ring held in proper position, and the traction and suspension systems maintained in efficient working order.

Nursing Care.—Experienced nursing care is essential. The leather covering of the ring, particularly the under portion, is apt to become wet and soiled. This should be washed and dried every day and the leather rubbed with either saddle soap or powdered shaving soap to keep it soft and pliable. The skin over the back and buttocks must receive daily care and special attention should be paid to that part of the skin in contact with the ring. If the pressure upon the tuberosity is excessive, the patient should

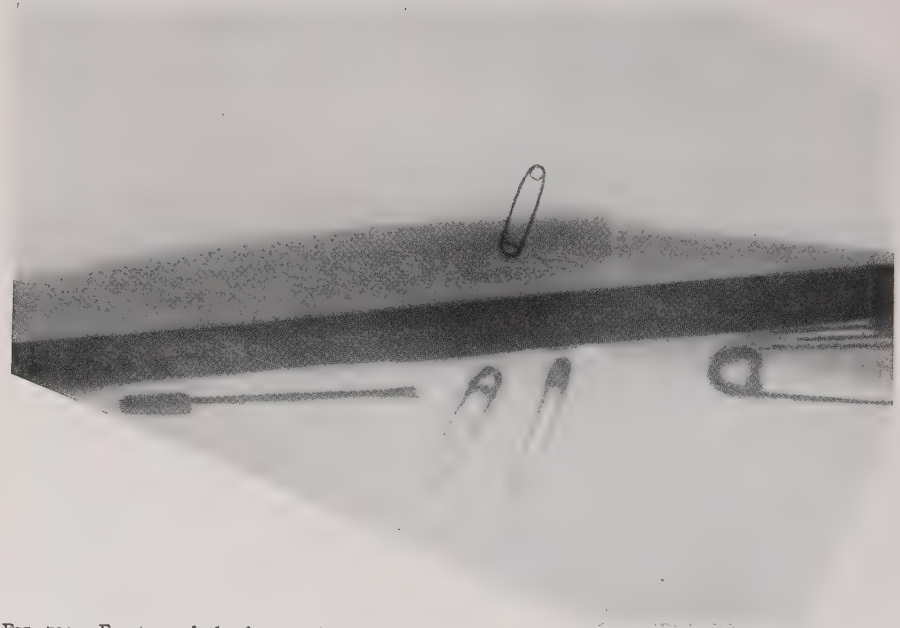


FIG. 709.—Fracture of the femur. (Same as Figs. 707, 708.) Reduction by the application of direct skeletal traction with "ice tongs." Lateral view. (Fracture Service, M. G. H.)

be taught to change the point of contact by alternately pulling the skin upward or downward with his own fingers.

Mobilization of the Knee.—Nélaton's dictum that a fracture of the femur requires treatment for a hundred days is a safe guide to follow, although the period is entirely too short if unprotected weight-bearing is intended. The union is usually sufficiently solid at the end of six to eight weeks to permit movement of the knee, although with the method of skeletal traction this may be begun much earlier. If the skin traction method has been employed, the long extension strips should be replaced by short ones, beginning at the knee and extending upward on the thigh. The hinged leg support should be attached to the splint and its end suspended by a cord which, by means of overhead pulleys, is brought within convenient reach of the patient's hands. By pulling and releasing this cord the patient may be taught to mobilize his own knee.

Caliper Splint.— At the end of eight to twelve weeks the callus is generally solid enough to allow protected weight-bearing. Evidence to this effect is obtained by observing that the seat of the fracture is no longer tender, that the union is firm on palpation, and that the roentgen examination demonstrates good callus formation. A caliper splint must be used

FIG. 710.—Roentgenogram showing pressure pad in position to correct displacement in the antero-posterior plane. In this case, over-correction of the original deformity has been obtained. (Fracture Service, M. G. H.)

(see page 501) to take the major part of the body weight and protect the callus from strain (Figs. 713-715). In the average case the patient will be allowed to walk with a caliper splint at the end of nine to ten weeks and the use of the splint will be continued for another ten weeks. Bowing of the femur with angulation and shortening or actual refracture are the penalties of unrestricted use of the leg at too early a period.

Physiotherapy.—Physiotherapeutic treatment should be begun at an early period and continued until complete recovery has been obtained. Massage of the thigh and knee should be instituted as soon as freedom from dressings permits. The patella should be kept movable and mobilization of the knee begun as early as possible. From the very beginning

the patient should be taught to actively contract the quadriceps muscle without moving the knee, and by persisting in this several hundred times daily a strong, healthy muscle may be built up. Baking and active voluntary movements of the knee should be begun as soon as active weight-

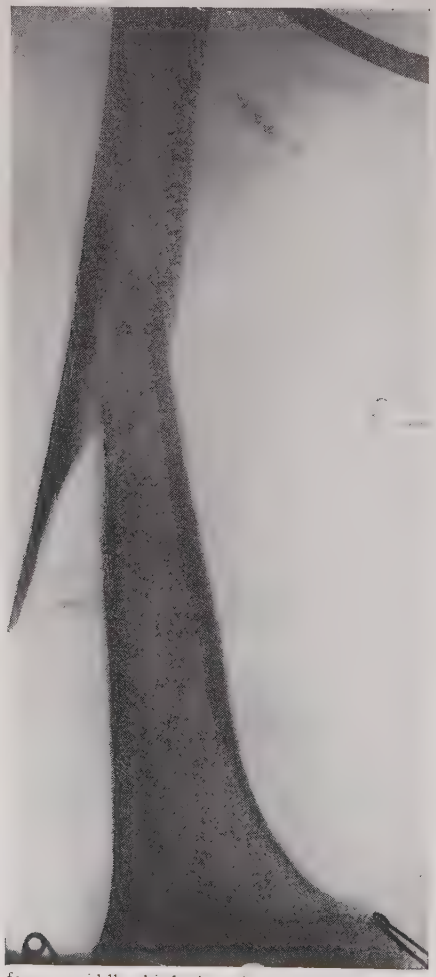


FIG. 711.—Fracture of the femur, middle third. Anterior view before reduction, showing characteristic external angular deformity. (Fracture Service, M. G. H.)

bearing is permitted, the caliper splint being removed daily for this purpose.

FRACTURE OF THE FEMUR IN CHILDREN

General Features.—Fracture of the femur is a common accident in children and may be of the greenstick variety with angular deformity or of the complete type with over-riding displacement. The injury does not

differ in its essential features from that of adults save that the persistence of a certain amount of deformity is a less serious matter because this tends to be corrected in the course of a few years by the process of growth.

Overhead Extension.—In children under the age of four the most satisfactory method of treatment is by vertical overhead extension

FIG. 712.—Method of applying Thomas splint with hinged knee attachment and two-way traction. Useful in the later stage of treatment of a fracture of the femur. (Fracture Service, M. G. H.)

(Fig 716). A Bradford frame with an opening for the buttocks is placed under the body. The extension strapping is applied to the entire length of the leg in the usual manner, the limb is elevated to a vertical position at a right angle to the bed and suspended from the overhead frame by means of a weight and pulley. The authors are in the habit of suspending

713

714

715

FIGS. 713, 714 and 715.—Brace for convalescent treatment of fractures of the femur. Thomas caliper splint. The ischial tuberosity rests upon the ring and by this means much of the body weight is removed from the injured leg. (713) View of splint, showing the lower end inserted in its socket in the heel of the shoe. (714) Splint applied. Anterior view. (715) Same, lateral view. (Fracture Service, M. G. H.)

the affected limb only as more effective counter-traction is obtained from the weight of the body than when both legs are suspended. The child is retained in position on the Bradford frame by means of a swathe encircling both frame and pelvis.

Other Methods of Treatment.—Principally from the likelihood of secondary displacement occurring in a plaster cast the authors do not recommend the use of the reduction and fixation method of treatment, although with small children it has yielded a considerable number of good results. In older children the fracture is best treated in a small size Thomas splint, using the fixed, integral type of traction. Skeletal traction with calipers ought not to be employed except in the case of extreme deformity, as there is danger of placing the points in the epiphyseal cartilage and of injuring it.

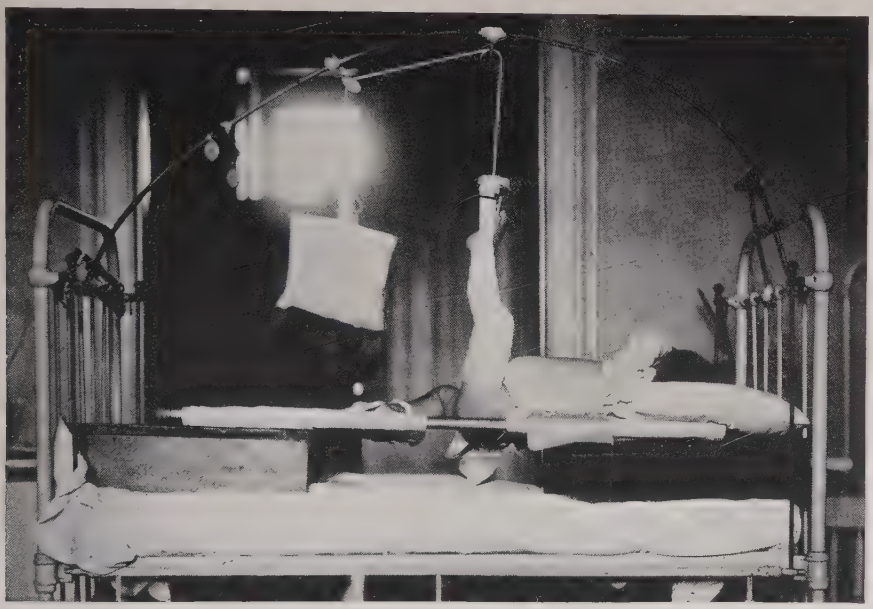


FIG. 716.—Fracture of the femur in a small child. Method of obtaining overhead traction. Note the Bradford frame on which the child is lying and the swathe which retains the pelvis in position. (Fracture Service, M. G. H.)

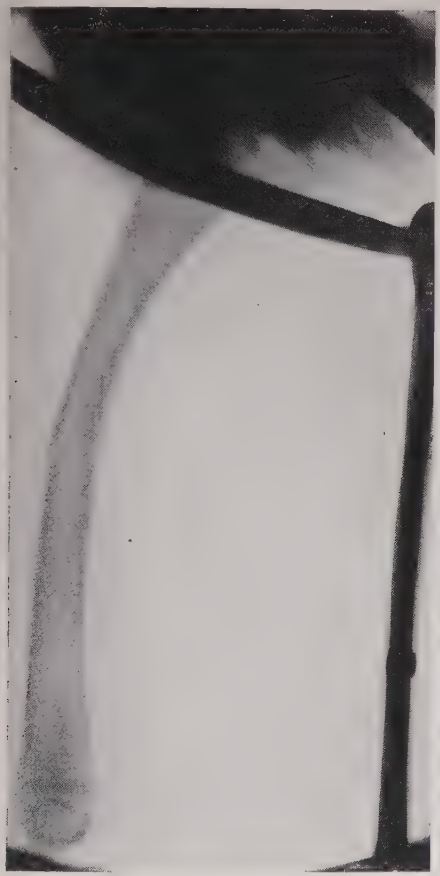
After-treatment.—Union is usually solid in four to six weeks, and because of the rapid formation of callus it is very difficult to change the position of the bones even at the end of the first week. A plaster of Paris spica may be applied at the end of a month and worn as a convalescent brace for an additional month, when weight-bearing may usually be permitted. Because of the expense and the short period of use a caliper splint is scarcely indicated.

717 718 719

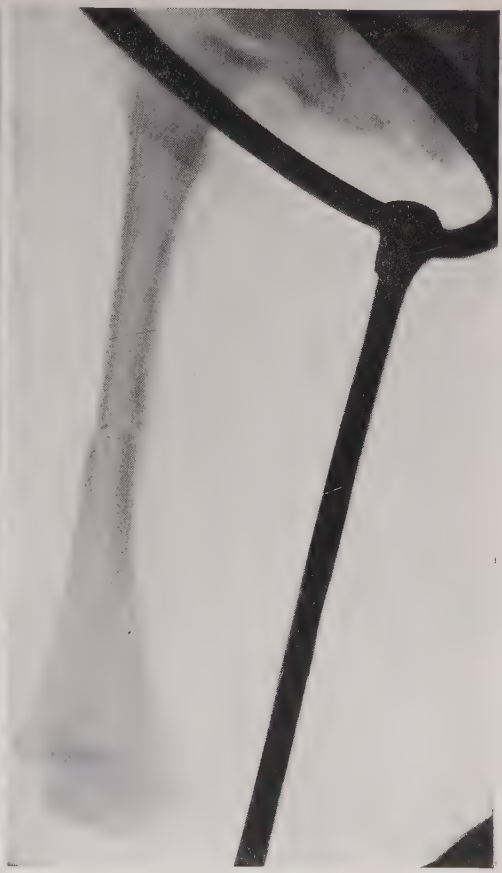
FIGS. 717, 718 and 719.—Roentgenograms of fracture of the femur in child, treated by method of overhead traction. (717) Original deformity. (718) Following reduction by traction, antero-posterior view. (719) Same, lateral view. (Fracture Service, M. G. H.)

OPEN OPERATIVE TREATMENT

Open Reduction.—Failure to obtain correction of deformity by the procedures previously described is generally due to interposition of muscle tissue between the fragments. In such cases union is often considerably delayed, and both from the standpoint of securing better alignment and



720



721

FIGS. 720 and 721.—Fracture of the femur in a child, following reduction. Too old for overhead traction; treated in Thomas splint. Good alignment. (720) Anterior view. (721) Lateral view. (Fracture Service, M. G. H.)

of hastening the healing process it is advisable to secure replacement of the bones by open operation. Internal fixation of the fragments is rarely required if, following the operation, the limb is replaced in the traction splint and skeletal traction applied. The femur is usually best approached by means of an incision on the lateral aspect of the thigh, following down the groove between the biceps and vastus lateralis muscles or splitting the fibres of the latter muscle itself.

Ununited Fractures.—Ununited fractures require the operation of bone grafting. The bones are exposed, their eburnated ends removed, and the medullary cavity widely opened. They may then be fixed in good position and held by means of a sliding inlay graft or by a massive bone transplant from the tibia. It is a wise procedure to fix the graft in position with

FIG. 722.—Ununited fracture of the lower end of the femur.

beef-bone screws. The introduction of metal plates or screws is likely to prove inimical to the process of healing.

Malunion.—Malunion is best treated by osteotomy to correct the most conspicuous feature of deformity, rather than by an effort to free the original fragments at the site of union and secure accurate reposition. The latter operation is much more difficult, involves more risk to the patient and is likely to result in failure, particularly when correction of shortening is the goal. A procedure for lengthening the femur in cases of very marked

shortening has recently been described by Putti.[2] A long Z-shaped osteotomy of the midportion of the shaft is first performed. Long metal

FIG. 723.—Malunited fracture of upper end of the femur. (Edinburgh Royal Infirmary.)

pins are then screwed into the lateral surfaces of the greater trochanter and external condyle, the ends protruding through the skin. To these a

[2] V. Putti, *Journ. Amer. Med. Asso.*, Sept. 17, 1921, p. 934.

long screw extension instrument of steel is applied and by twisting the handle the bone pins are forced apart and the femur lengthened. Lengthening of as much as 7.5 cm. has been obtained.

Stiffness of the Knee.—Limitation of the ability to flex the knee, following a simple, uninfected fracture, is almost always due to extensive

FIG. 724.—Correction of old malunited fracture of the femur. Fixation with bone graft. (Fracture Service, M. G. H.)

scar-formation in the region of the fracture, which binds down the quadriceps muscle and limits its extensibility. The knee-joint is normal on both clinical and Roentgen examination. The range of movement tends to increase gradually for a considerable period, but if, after two or three years of active use the amount of flexion is still much limited and insuffi-

cient for the ordinary needs, the advisability of lengthening the quadriceps tendon according to the method of Bennett[3] should be considered.

Lengthening of the Quadriceps Tendon.—The tendon is exposed through a long, anterior incision and divided in a V-shaped manner, the apex of the V pointing proximally. The knee is then flexed to a right angle which separates the apices of the angular incisions and lengthens the tendon. The gap is then closed by suturing the lateral margins of the opening in the midline. The leg is immobilized for six weeks in a plaster of Paris casing with the knee flexed, after which active weight-bearing is permitted. Following the operation there is weakness of the quadriceps muscle for a long period, and inability to completely extend the knee may persist for as long as one year.

COMPOUND FRACTURE OF THE FEMUR

Wound Treatment.—The treatment of compound fractures of the femur in its broad lines corresponds to the general plan described in the special section on compound fractures. Thorough débridement should be performed as soon as possible after injury, followed by immediate closure in the case of a small wound or by chemical sterilization according to the Carrel-Dakin method in the case of a dirty wound. When infection develops, wide drainage is indicated, and the limb should be kept as nearly as possible in the horizontal plane, as otherwise under the influence of gravity the pus tends to track upward along the muscle planes, and extension of the sepsis and improper drainage result.

Fixation.—Fixation is best obtained by the use of a Thomas splint in conjunction with skeletal traction by the caliper method. This provides maximum exposure of the region of the wound without detriment to proper alignment of the bones. When the wound is dressed the supporting band beneath the seat of injury may be removed temporarily to give additional exposure, the adjacent bands being tightened as a preliminary in order to avoid change in the position of the fragments.

[3] G. E. Bennett, *Journ. Bone and Joint Surgery*, April, 1922, p. 279.

CHAPTER XVI

INJURIES IN THE REGION OF THE KNEE

I. FRACTURES OF THE FEMORAL CONDYLES
II. SEPARATION OF THE LOWER FEMORAL EPIPHYSIS
III. FRACTURE OF THE TUBEROSITIES OF THE TIBIA
IV. SEPARATION OF THE UPPER EPIPHYSIS OF THE TIBIA
V. SEPARATION OF THE TIBIAL TUBERCLE
VI. FRACTURE OF THE PATELLA
VII. DISLOCATION OF THE PATELLA
VIII. DISLOCATION OF THE KNEE
IX. INTERNAL DERANGEMENT OF THE KNEE-JOINT
1. Injury of the Lateral Ligaments
2. Injuries of the Semilunar Cartilages
3. Injury of the Crucial Ligaments
4. Fracture of the Tibial Spine
5. Injury of the Infrapatellar Fat Pad
6. Loose Bodies

ANATOMY OF THE KNEE

Lower End of the Femur.—At its lower end the shaft of the femur expands and terminates in two rounded condyles. The lateral condyle is the larger and lies in the saggital plane, while the smaller mesial condyle is set more obliquely. The anterior inferior and posterior surfaces of the condyles are covered with articular cartilage. On the anterior aspect these surfaces join to form the trochlea, but inferiorly and posteriorly they are separated by the inter-condylar fossa. The mesial and lateral borders of the articular surfaces are marked by the condylar ridges, which can be palpated in the normal knee when the joint is flexed. The lateral and mesial surfaces of the condyles are rough for the attachment of ligaments, and the inner condyle is surmounted by the prominent adductor tubercle, which provides the point of attachment for the tendon of the adductor magnus. Above the condyles on the posterior aspect of the femur is a flat triangular area, the trigone, which forms the bony floor of the popliteal space.

Upper End of the Tibia.—The upper end of the tibia is formed by the shelving expansion for the tuberosities. The superior surface is flat and approximately oval in outline. It is occupied by two oval articular facets which in the midline are separated by a ridge of roughened bone from which arises the tibial spine with its twin peaks. The tibial tuberosities overhang the tibial shaft posteriorly and are here separated by the popliteal notch. The anterior surface of the upper end of the tibia curves forward and downward from the articular margin and gives rise to the triangular-shaped prominence of the tubercle, whose lower portion is roughened for the attachment of the patellar tendon.

Patella.—The patella is oval in shape with a smooth articular surface on the joint side and a roughened surface externally. Being a sesamoid, it has no periosteum.

Ossification.—The osseous centre for the lower epiphysis of the femur is usually present at birth, but does not unite with the shaft before the age of twenty. The epiphyseal junction is cup-shaped, and lies in the transverse plane just below the level of the adductor tubercle. It lies entirely outside the capsule of the knee-joint, although in close relation to the superior prolongation of the joint above the patella.

The osseous centre for the upper end of the tibia is present at, or appears soon after, birth, and it also joins the shaft about the nineteenth or twentieth year. The entire upper end of the bone is included in the epiphyseal cartilage, but the line of junction with the shaft lies below the capsular attachment. It runs transversely across the tibia, but has a beak-like projection extending downward from its anterior surface for the tibial tubercle. In other instances the tubercle develops from a separate centre of ossification which appears anywhere from the eighth to the fourteenth year and unites with the main epiphysis a short time afterward. On account of the attachment of the patellar tendon this is subjected to a large degree of strain and may easily become detached.

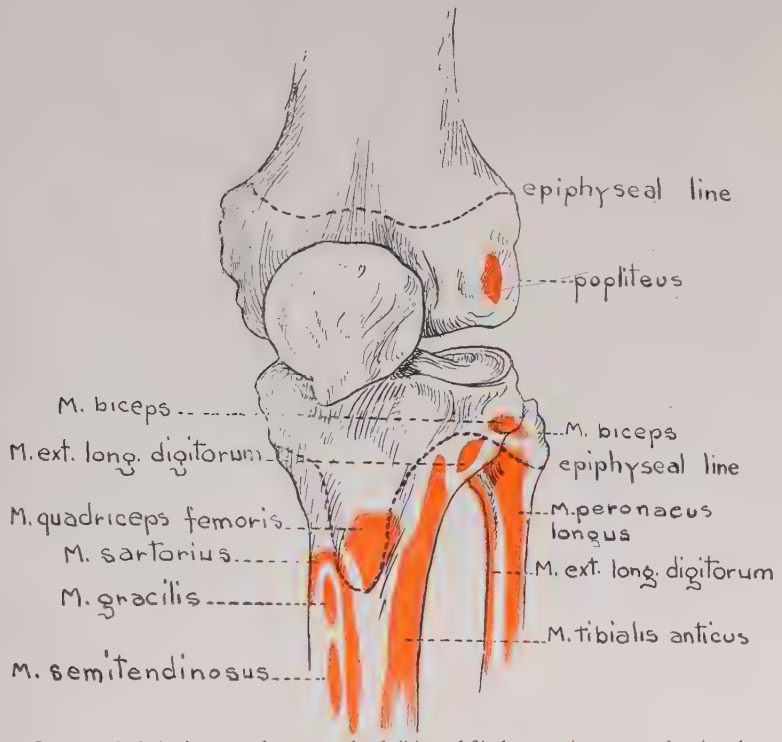


FIG. 725.—Lower end of the femur and upper ends of tibia and fibula, anterior aspect, showing the points of muscle attachment and the epiphyseal lines.

The centre of ossification for the patella first appears from the second to the fifth year. Ossification spreads from this small point until the patella is fully formed at about twenty. Occasionally there are two separate centres of ossification which, in case fusion fails to occur, give rise to a bipartite patella.

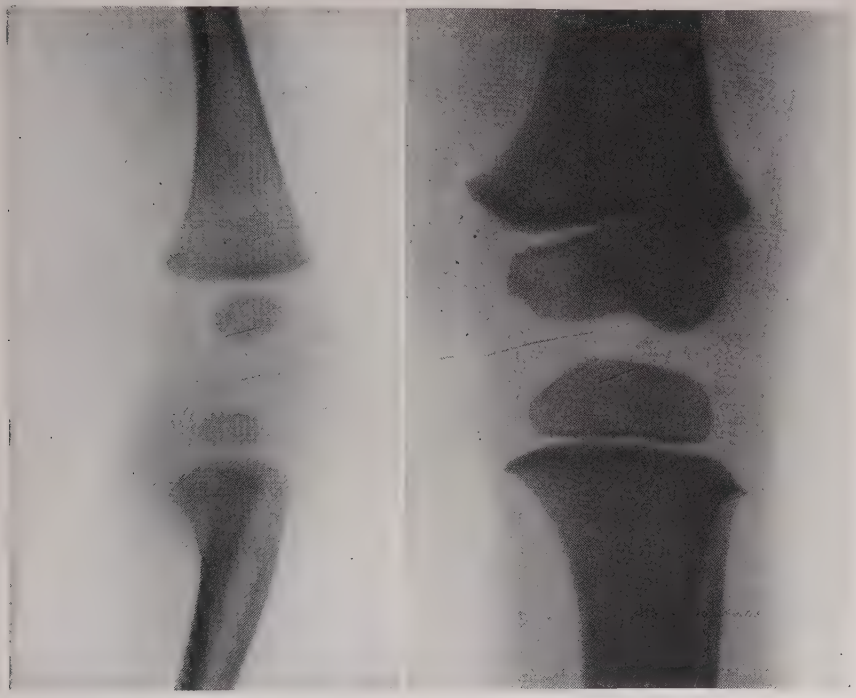
The Knee-joint.—That the knee-joint is one of the strongest joints in the skeleton is shown by the fact that though exposed to great strain, it is seldom dislocated. It owes this stability not so much to the shape of the bones that enter into its formation, but more to the strength and arrangement of its ligaments.

The capsule is attached below to the margins of the superior surface of the tibia and above to the mesial and lateral borders of the condylar articular surfaces. In addition, there are capsular prolongations above the condyles, behind, and a large pouch extending upward under the quadriceps tendon, in front, which function as bursæ for the gastrocnemius and quadriceps muscles. The suprapatellar bursa or pouch is of importance as it may expose the knee-joint to injury and infection in fractures considerably removed from the articular surface.

726 727 728

FIGS. 726, 727 and 728.—Development of the epiphyses of the knee. Lateral roentgenograms. (726) Age of two years. (727) Age of three years. (728) Age of ten years.

The Semilunar Cartilages.—The semilunar cartilages are interposed between the joint surfaces, lying on and partially encircling the articular facets of the tibia. The internal semilunar is in the shape of the letter "C," while the external one is completely circular, like the letter "O," and is also larger. The cartilages are triangular on cross section. The base is formed by the thickened peripheral border and is attached to the capsule and the margin of the tibia by the coronoid ligament. The apex is represented



729 730

FIGS. 729 and 730.—Development of the epiphyses of the knee. Antero-posterior roentgenograms. (729) Age of seven weeks. (730) Age of two years.

by the thin, central margin and lies entirely free within the joint. The two extremities of the internal semilunar are attached to the bony depressions which lie in front of and behind the tibial spine, while the mesial border of the external cartilage is also attached in the same region. The internal cartilage is closely joined to the capsule, particularly at its mesial aspect, where the fibres attaching it mingle with those of the internal lateral ligament. The external cartilage has a much looser attachment and a much greater freedom of motion. The much greater liability of the internal cartilage to injury finds its explanation in this close connection to the capsule, by reason of which it is likely to be displaced or detached whenever the internal lateral ligament is injured. The function of the semilunar cartilages is to deepen the articular facets of the tibia and also to serve as buffers between the joint surfaces. Their removal apparently causes no interference with function.

The Lateral Ligaments.—The lateral ligaments of the knee are two. The internal one is short and thick and can be separated from the capsule only by artificial dissection. It is also intimately associated with the internal meniscus. The external ligament is longer and runs from the lateral surface of the external condyle to the head of the fibula. It is entirely separated from the capsule.

The Crucial Ligaments.—The crucial ligaments are the strongest in the knee. The anterior crucial ligament arises from the tibia just in front of the spine and runs upward,

backward, and outward to the posterior portion of the inner side of the lateral condyle. The posterior crucial ligament arises from the depression in the superior surface of the tibia behind the spine and runs upward, forward, and inward to be attached to the front of the outer side of the inner condyle. The anterior ligament is tight in extension, while the posterior one is tight in flexion and internal rotation. Abnormal mobility in the antero-posterior direction when the knee is extended is the sign of damage to

731 732

FIGS. 731 and 732.—Development of the epiphyses of the knee. Antero-posterior roentgenograms. (731) Age of three years. (732) Age of ten years.

the anterior ligament, while increase in antero-posterior mobility when the knee is flexed is the sign of injury to the posterior ligament. Damage to either one causes instability and weakness of the knee.

Posterior Ligaments.—On the posterior surface of the knee the capsule is reinforced by certain structures which blend more or less with it. The tendon of the semimembranosus, which is inserted in a groove on the inner side of the tibia, sends off fibres which run obliquely upward across the capsule (ligament of Winslow). The popliteus muscle arising from the outer condyle of the femur runs obliquely downward and inward across the capsule to its insertion in the upper end of the tibia. The two heads of the gastrocnemius muscle which take origin from the posterior surface of the femur, above the condyles, also blend with the capsule.

The Anterior Covering of the Knee.—Anteriorly the joint is covered by the quadriceps tendon, the patella, and the patellar tendon, the last named being separated from the capsule and upper margin of the tibia by a thick pad of fat and a small bursa. The insertion of the quadriceps is much more extensive than usually supposed, broad, fibrous expansions descending on either side of the patella and patellar tendon from the vastus lateralis and vastus medialis muscles and blending with the fascia of the leg. As in

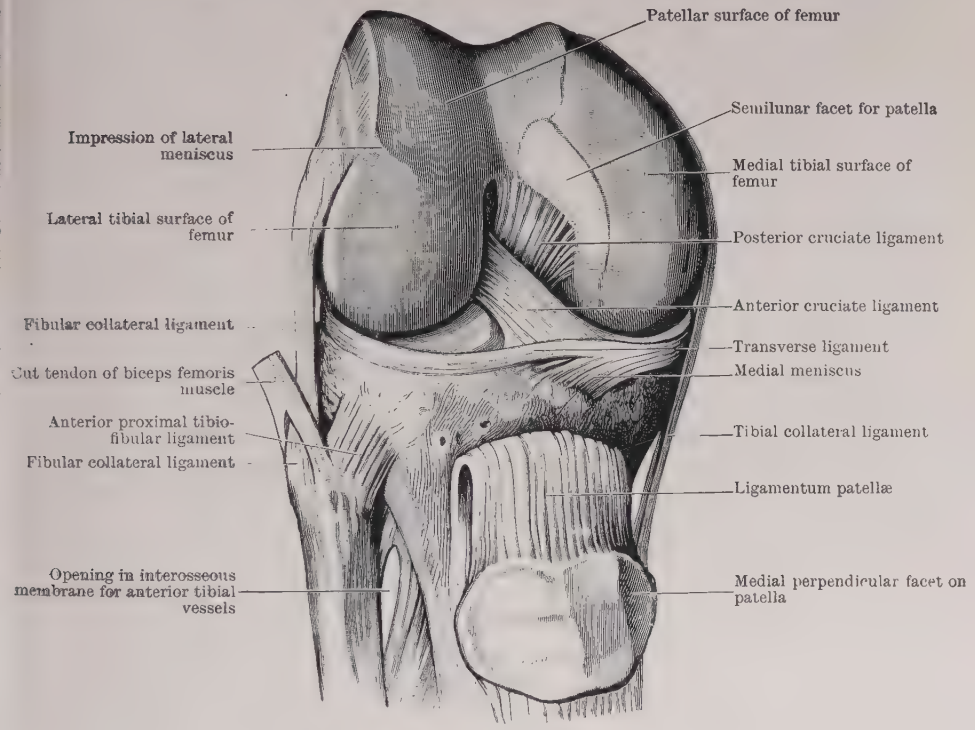


FIG. 733.—View of the knee-joint with the capsule removed and the patella turned downward. (Cunningham: Text-book of Anatomy.)

fracture of the olecranon, so in fracture of the patella, separation of the fragments can occur only when the lateral expansions are torn. If open operative treatment is employed, it is usually sufficient in order to secure approximation to repair the lateral tears.

Vessels and Nerves.—In the popliteal space lie the important neuro-vascular structures. Although in close relation to the back of the femoral condyles, the artery and vein are seldom damaged by fracture on account of the interposition of a thick fat pad. Injury is most likely to occur in separation of the lower femoral epiphysis when the shaft is displaced downward and backward. The sciatic nerve usually divides into the external and internal popliteal nerves some distance above the condyles, and the external nerve in its oblique course along the internal border of the biceps tendon, and particularly as it winds about the head of the fibula, is more exposed to injury than the internal popliteal nerve, although the latter is situated more deeply. There is an abundant arterial anastomosis about the knee, through the articular branches which come off the popliteal artery in pairs above and below the joint and also through branches of the anastomotica magna which is given off at a higher level.

Movements of the Knee.—Motion at the knee-joint is a composite movement of rotation of the condyles and gliding in the antero-posterior direction. Flexion and

extension take place between the condyles and the semilunar cartilages, while rotation has its seat between the cartilages and the upper surface of the tibia. In semiflexion the joint is in its most unstable position and least protected from injury. Complete extension is accompanied by an outward rotation of the tibia, a screwing home, as it were, of the joint, by which all ligaments are tightened and the maximum of stability obtained. Complete extension in most individuals is equivalent to slight hyperextension.

The patella moves upward and downward on its articular bed between the condylar ridges in movements of extension and flexion. In complete extension the patella may lie completely above the trochlea. In flexion the patella engages between the ridges, but lies chiefly on the outer condyle. Dislocation outward is prevented by the external condylar ridge and by the restraining pull of the patellar tendon.

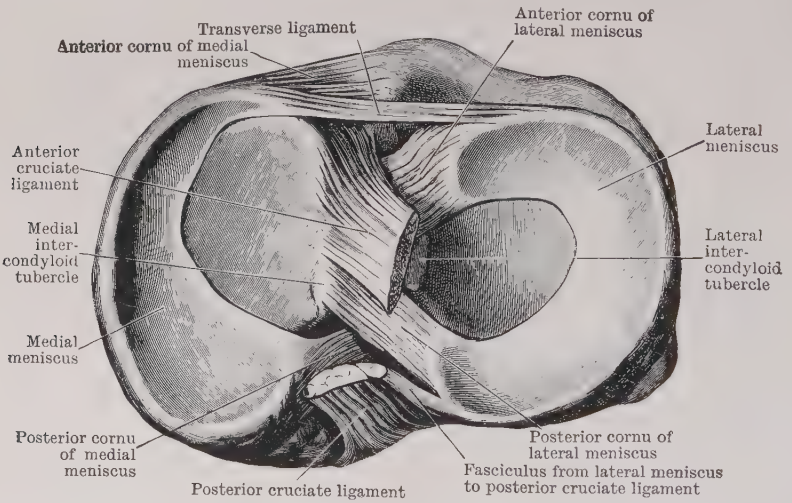


FIG. 734.—Upper surface of tibia viewed from above, showing semilunar cartilages. (Cunningham: Text-book of Anatomy.)

I. FRACTURES OF THE FEMORAL CONDYLES

Intercondyloid or "T" Fracture.—The common fracture of the condyles is the intercondyloid or "T" fracture extending into the knee-joint. It is in reality a supracondylar fracture produced by direct violence, in which the temporary continuation of the force causes the shaft to be driven in between the condyles with a resulting split extending vertically downward and with separation and comminution of greater or less extent. It occasionally takes place in persons whose bones have been previously weakened either by senile changes or arthritic processes and may follow a simple fall on the knee. The diagnosis usually depends upon the roentgenological examination, although the soft boggy feeling of the condyles, the distention of the knee-joint with blood, and the demonstration of a supracondylar fracture of the femur may suggest the true nature of the lesion (Fig. 739).

Treatment.—The importance of the injury lies in the direct involvement of the knee-joint and the alteration in the shape of the articular sur-

faces. Inability to obtain complete replacement of the condyles is almost certain to result in limitation of joint motion and a weak and painful knee.

Skeletal Traction.—Skeletal traction by means of a Steinmann pin passed through the crest of the tibia just below the level of the tibial tubercle

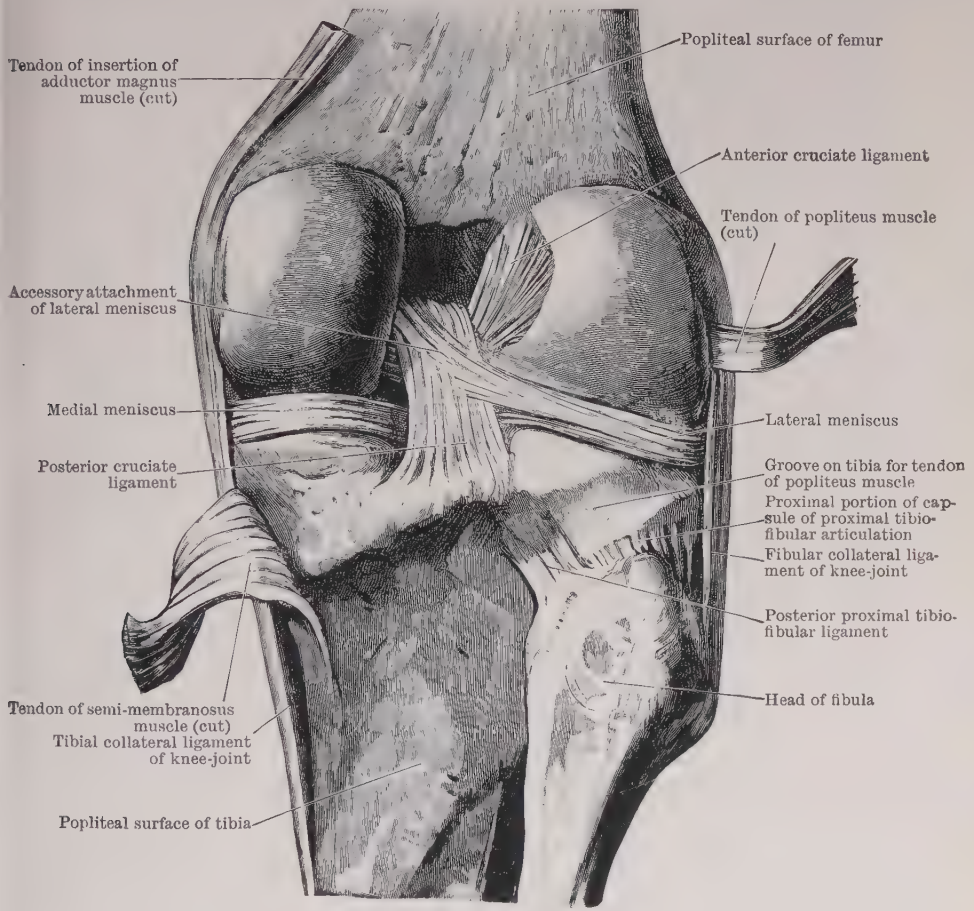


FIG. 735.—Posterior view of the knee-joint showing the chief ligaments. The capsule has been removed. (Cunningham: Text-book of Anatomy.)

seems to offer the greatest hope of obtaining correction of deformity. A Thomas splint with hinged leg support is used, the knee being placed in a position of moderate flexion in order that the line of pull through the front of the tibia may correspond as nearly as possible to the axis of the shaft of the femur and also in order to secure relaxation of the gastrocnemius muscle, which is responsible for a certain amount of the deformity (Figs. 740 to 744). Extension tends to restore the normal outline of the condyles by exerting tension upon the ligaments and surrounding soft

parts. It also overcomes shortening and separates the joint surfaces, the latter being of importance in preventing the formation of adhesions and contracture of the capsule. The method of splinting also permits a slight degree of movement at the knee-joint from the beginning. Union is usu-

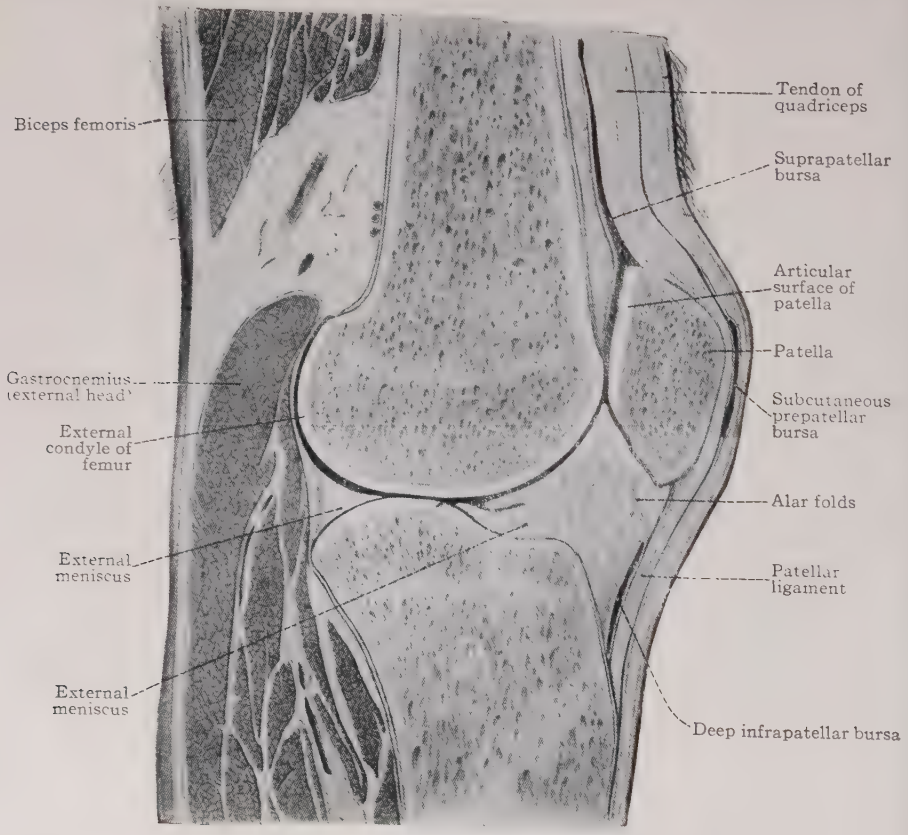


FIG. 736.—Sagittal section through knee-joint. (Sabotta: Human Anatomy.)

ally solid in six to eight weeks, and the remainder of the treatment is similar to that of a supracondylar fracture.

Manipulative Correction with Clamp.—If, after the use of extension for several days, the condyles still remain separated, further improvement in position may be obtained by the application of a clamp as suggested by Scudder. An ordinary carpenter's screw clamp with a broad span may be used (Fig. 745). Under light anæsthesia and without disconnecting the extension weight or removing the Thomas splint, this is applied to the mesial and lateral surfaces of the condyles, a felt pad being interposed between the instrument and the skin. The screw is turned down, thus forcing the condyles together. The clamp is then removed, the corrective

influence of the extension being sufficient to maintain the position, and no special form of dressing is required other than that previously mentioned.

Operative Fixation.—In some cases internal fixation of the condyles by means of a wire bolt and nuts may be indicated (Fig. 763), but the dis-

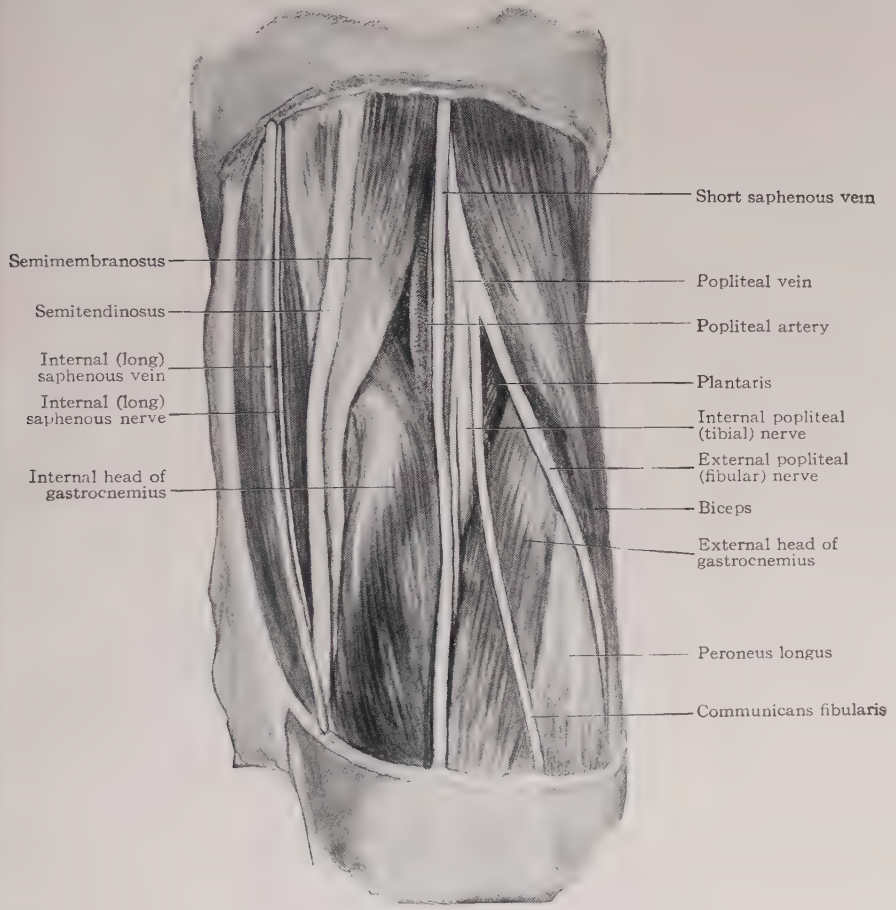


FIG. 737.—The popliteal space. (Davis: Applied Anatomy.)

astrous result if infection should develop must always be borne in mind when considering such a procedure. The metal bolt or screw should be removed as soon as the union is fairly solid, usually at the end of four to six weeks.

Avulsion Fractures.—Rarely a small fragment may be split off a single condyle as the result of abduction or adduction strains of the knee (Fig. 739). Replacement is to be obtained by manipulation of the knee in the opposite direction to that which produced the injury and by immobilization in a plaster of Paris casing extending from the ankle to the groin.

II. SEPARATION OF THE LOWER FEMORAL EPIPHYSIS

Occurrence.—The lower epiphysis of the femur is a fairly frequent site of epiphyseal strain and in addition is not uncommonly completely separated. The latter injury occurs chiefly in boys between the ages of eight and fourteen years and is the result of extreme violence with rotation and

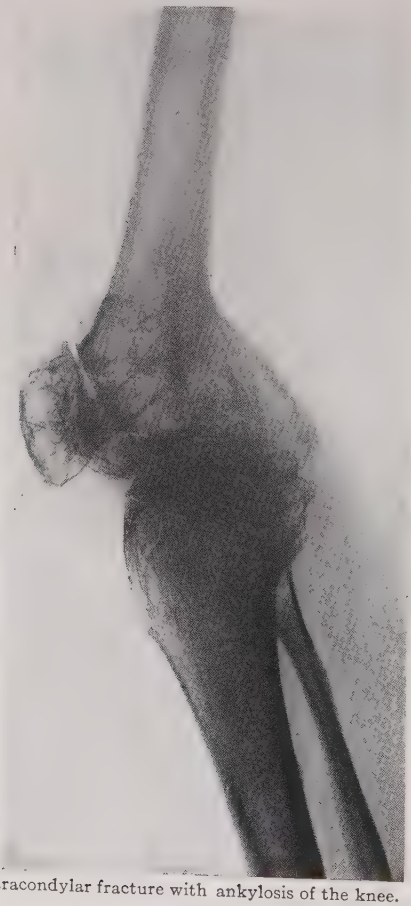


FIG. 738.—Old malunited intracondylar fracture with ankylosis of the knee. (Fracture Service, M. G. H.)

hyperextension of the knee. Because a singularly large proportion of the cases have resulted from the leg becoming engaged in the spokes of a wheel while climbing on or jumping off a moving vehicle, the injury has been aptly called the " cart-wheel fracture."

Displacement.—The displacement is classical (Fig. 746). Although the region of attachment of the gastrocnemius muscle to the back of the femur extends upward from the condyles across the epiphyseal line, the injury strips loose the diaphyseal origin so that only the condylar attachment is preserved. The denuded end of the shaft is displaced downward and back-

ward into the popliteal space, where it may injure the vessels or even protrude through the skin. The epiphyseal cartilage is rotated by the gastrocnemius muscle into a position of right-angle flexion and lies in front of the diaphysis. The capsule of the knee-joint is seldom damaged (Fig. 747).

Diagnosis.—The diagnosis is made from the age of the patient, the character of the violence, and the typical appearance of the deformity.

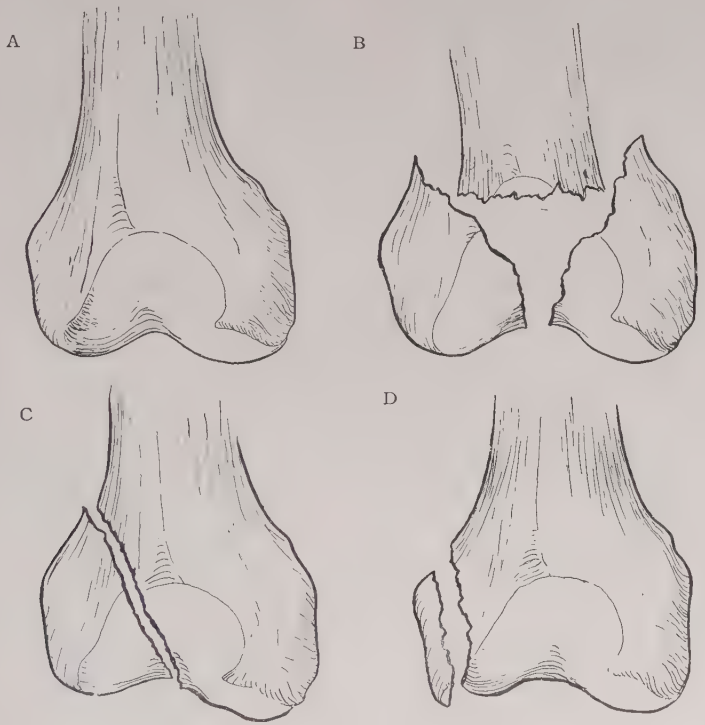


Fig. 739.—Diagrammatic representation of different types of fracture of the lower end of the femur. (A) Normal configuration. (B) Intracondylar fracture. (C) Fracture of a single condyle. (D) Avulsion fracture.

Abnormal mobility and shortening are present. The end of the diaphysis may be felt protruding under the skin in the popliteal space, and the flexed articular surface of the femur may be palpated, lying anteriorly. Circulatory disturbance of the lower leg from compression of the popliteal vessels is frequently present.

Reduction.—Treatment consists of reduction by manipulation under anæsthesia, followed by immobilization in plaster of Paris. In order to reduce the displacement it is necessary first to relax the gastrocnemius muscle by flexion of the knee. The patient is placed in the dorsal decubitus with the leg hanging downward over the end of the table in a position of right-angle flexion. One assistant pulls downward on the foot while

another supports the posterior portion of the thigh with his hands and makes counter-pressure upward (Fig. 748). The operator standing at the foot of the table places his hands on the posterior surface of the flexed leg close to the knee and exerts strong traction in the distal direction, which, assisted by gentle movements of rotation, accomplishes the replacement. Reduction is accompanied by a click or jar and a restoration of the normal

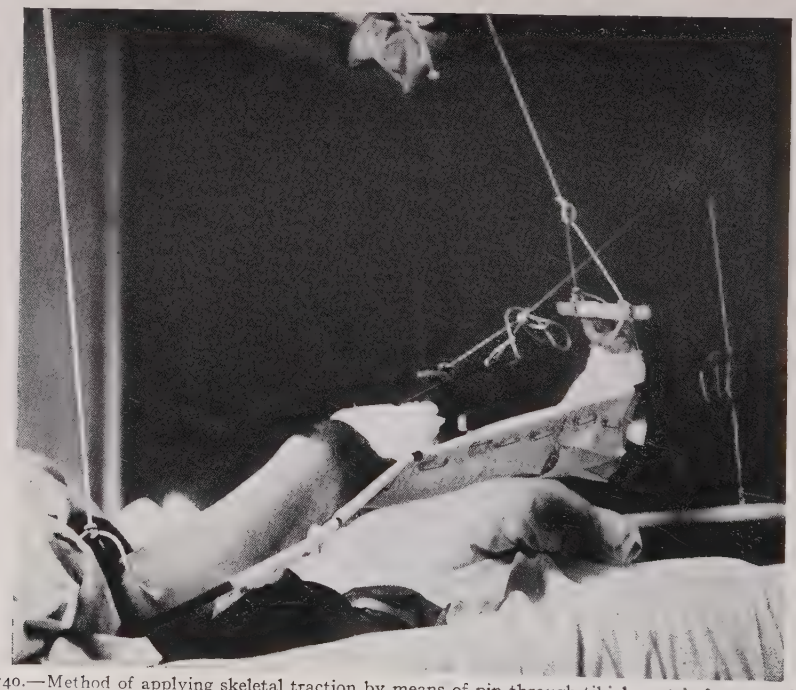


FIG. 740.—Method of applying skeletal traction by means of pin through tibial crest in fracture of lower end of femur. (Fracture Service, M. G. H.)

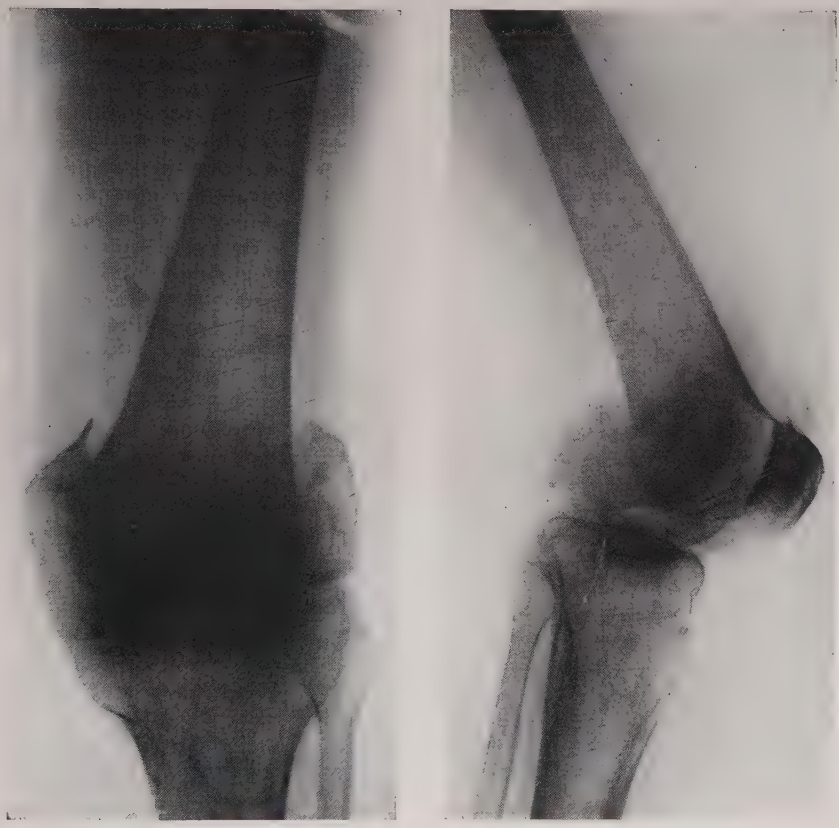
outline of the knee, which is readily recognized. The reduced position is comparatively stable as long as the knee is maintained in flexion, but the movement of extension is likely to cause a return of the deformity.

Splinting.—Immobilization is obtained by a plaster cast applied with the knee flexed, and extending from the toes to the groin (Figs. 749 to 753). At the end of four weeks this is removed, the knee extended, and a new casing reapplied. Weight-bearing may be permitted in the plaster at the end of six weeks, and all protection may be discontinued at the end of eight weeks from the time of injury.

III. FRACTURE OF THE TUBEROSITIES OF THE TIBIA

Types of Fractures.—The expanded upper end of the tibia is not infrequently the seat of fracture, usually involving the articular surface. The injury may take several different forms, depending upon the mode of pro-

duction and the severity of the violence. Compression may play the predominating rôle, as in the case of a fall upon the feet, the knee being abducted or adducted at the moment of impact. One of the femoral condyles is driven into the corresponding portion of the tibial plateau, and a depressed, impacted type of fracture results, or a vertical separation of



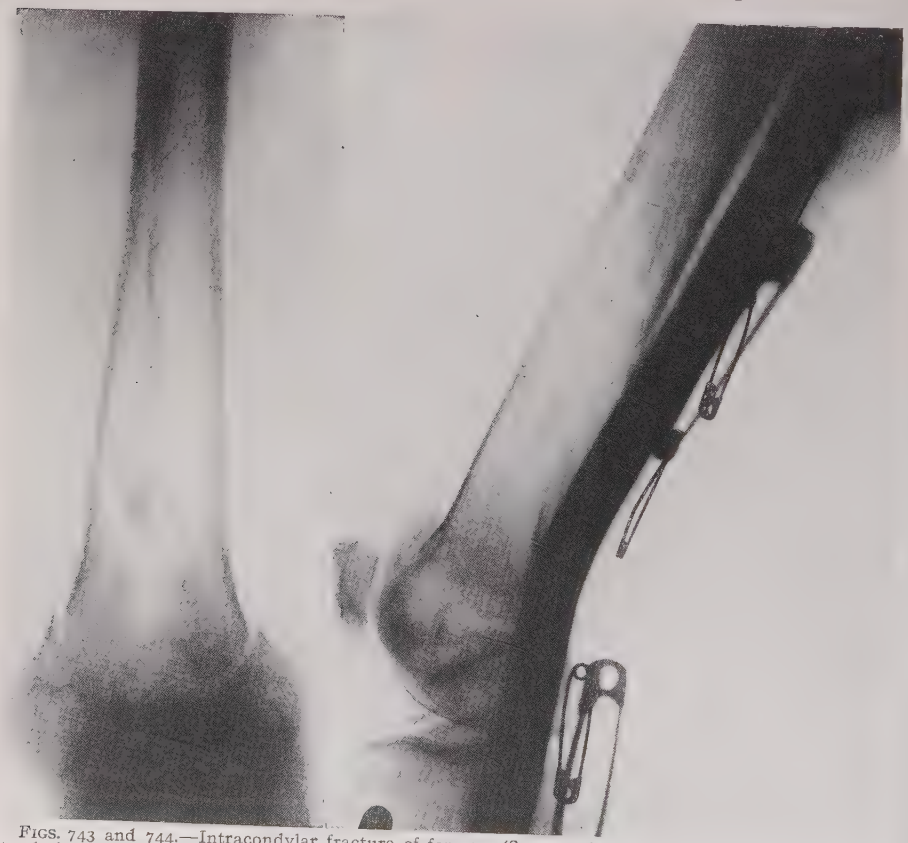
741 742

FIGS. 741 and 742.—Intracondylar fracture of femur. (741 and 742) Anterior and lateral views before reduction. (Fracture Service, M. G. H.)

one of the tuberosities. In other instances lateral strain upon the knee, as from violent abduction or adduction of the leg, plays the more important part, and a triangular fragment is split off from the articular margin. Still other cases are produced by a combination of both mechanisms, and occasionally direct violence may play a part. Such injuries are likely to be accompanied by considerable comminution and may involve both the inner and outer margins of the tibial plateau. A not uncommon type is the double oblique fracture of both tuberosities, resembling an inverted "V" or "Y." The integrity of the shaft is affected, and its upper end may

be forced upward between the fragments with consequent lateral displacement and shortening (Figs. 755 to 761).

Displacement.—With all the above types of injury it is common to find a considerable degree of bony deformity. This may take the form of wide horizontal separation of the fragments or depression of a portion of the



FIGS. 743 and 744.—Intracondylar fracture of femur. (Same as Figs. 741 and 742.) Anterior and lateral views showing reduction obtained by application of Thomas splint with direct skeletal traction. A Steinmann pin has been passed through the crest of the tibia. (Fracture Service, M. G. H.)

tibial plateau, or a combination of both. The first causes broadening of the articular surface of the tibia and uneven bearing; the second alters the axis of the joint, with resulting genu varum or valgum. Either one is of serious portent because of its effect upon the configuration of the joint. Incongruence of articular surfaces is abhorred by nature, and in the case of the knee, which is subject to constant and heavy strain, it almost always provokes a secondary traumatic arthritis, with a resulting weak and painful joint.

Treatment by Extension and Early Movement.—For this reason every effort should be made to secure replacement of the fragments and restora-

tion of the normal joint outline. In view of their dissimilarity no one single method of treatment should be expected to provide a universal remedy for all types of injury. In the majority of cases the treatment should employ the principles of traction and early movement, these being obtained by the use of a Thomas traction splint with movable leg support. Adhesive extension strips are applied to the mesial and lateral surfaces of the leg, extending from the ankle to the knee (Fig. 758). The fixed integral type

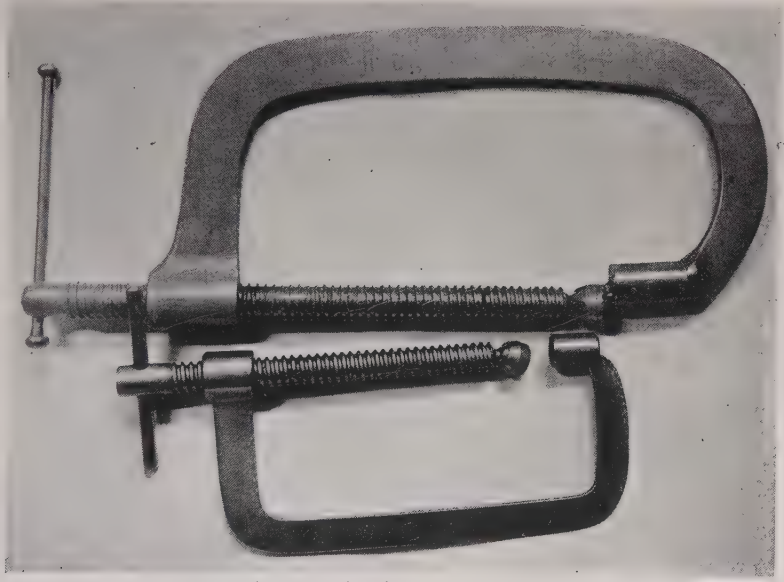


FIG. 745.—Scudder's bone clamps for approximating the fragments in intercondyloid fractures of the lower end of the femur or upper end of the tibia.

of traction is most suitable, the extension cords being fastened to the end of the hinged leg support and twisted by means of a stick to the desired degree of tension. Traction corrects alignment, and by exerting tension on the surrounding soft parts tends to cause replacement. In addition it produces separation of the joint surfaces and thus relieves the movable fragment of pressure from the opposing femoral condyle.

Reduction with Aid of Clamp.—If sufficient correction is not obtained by this means, a carpenter's screw clamp may be applied to the upper end of the leg and the tuberosities forced together. Brief anæsthesia is necessary for this procedure, and care should be used to avoid making pressure upon the external popliteal nerve as it winds around the neck of the fibula.

Movement of the Knee.—Mobilization of the knee may be begun at the end of two to three days. For this purpose it is not necessary to disturb the apparatus or loosen the extension, the hinged leg support alone being moved. At first the movements should be performed only three to five

times daily, but as the pain and spasm diminish, both their frequency and amplitude should be increased until finally at the end of two to three weeks they are repeated twenty to twenty-five times during two to three different periods of the day. Daily massage of the knee and of the muscles of the

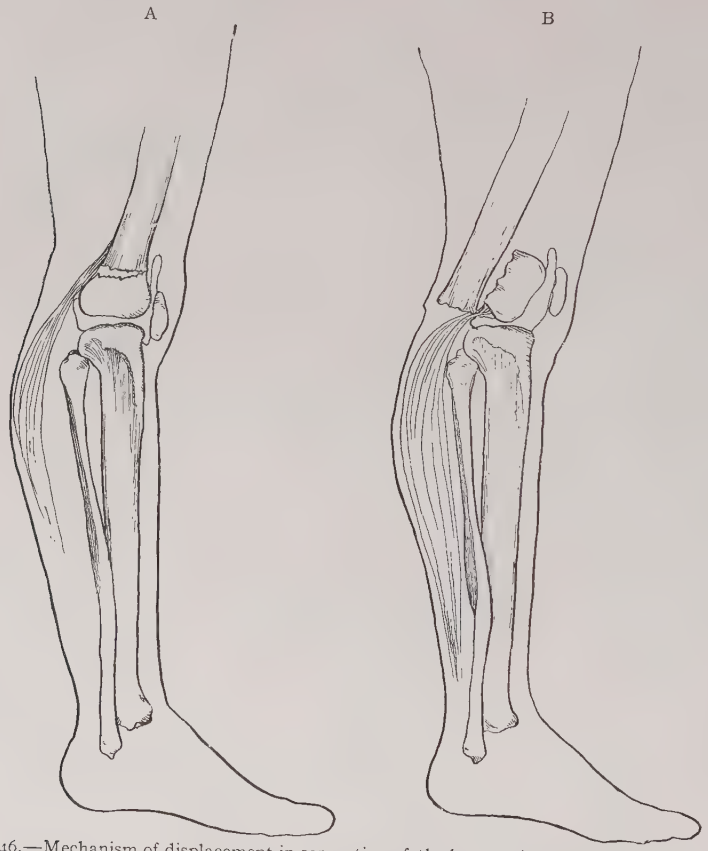


FIG. 746.—Mechanism of displacement in separation of the lower epiphysis of the femur. (A) Separation as a result of hyperextension. (B) Characteristic displacement with the shaft protruding downward and backward in the popliteal space and the epiphyseal cartilage lying anterior and flexed due to the action of the gastrocnemius muscle.

thigh should be begun immediately and is of considerable importance in reducing swelling and maintaining the tissues in good condition.

Operative Fixation.—Other types of injury, particularly those with double oblique fracture of both tuberosities or those with large single fragments and wide separation, are ideal for operative reduction and fixation. By means of small mesial and lateral incisions a wire bolt is passed through the whole thickness of the head of the tibia, and the fragments drawn together by screwing down a nut (Figs. 762, 763). Care is necessary to see that the fragments are in good position before bolting

them together, and for this it may be necessary to make a roentgen examination during the course of the operation.

Fractures with Slight Deformity.—Still other fractures with little deformity may be treated from the beginning in a bivalved plaster cas-

FIG. 747.—Specimen illustrating the usual displacement in separation of the lower femoral epiphysis. The characteristic deformity as represented in the previous diagram may be recognized. (Warren Anatomical Museum.)

ing extending from the ankle to the groin. This should be removed daily for massage and movement of the knee.

Convalescent Brace.—In all these cases union occurs rapidly and is generally quite solid at the end of six weeks. Non-union is almost unknown. Because of the tendency to develop angular deformity at the knee, unprotected weight-bearing should not be permitted until the end of three to five months, depending upon the completeness of replacement. Weight-bearing with the aid of a Thomas caliper brace may, however, be allowed at the end of six to eight weeks.

Excision of the Knee.—However, in spite of the most careful treatment

there are a certain number of cases, usually those with extensively comminuted fractures, which from the very nature of their injuries are doomed to disappointing results. Such cases represent a difficult problem and it is necessary either to abandon the patient to a life of permanent

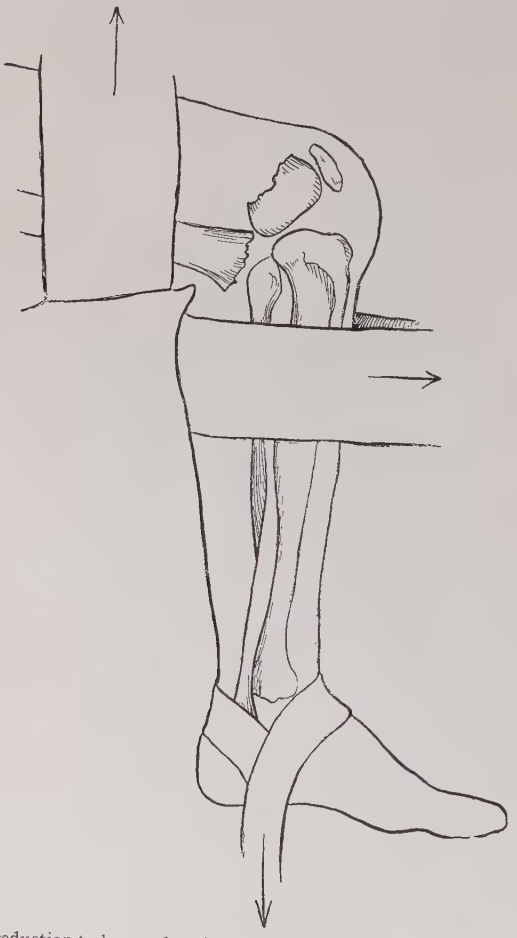


FIG. 748.—Method of reduction to be employed in separation of the femoral epiphysis; extension in two planes being necessary with the knee flexed.

disablement, relieved somewhat by the use of a brace, or to recommend the operative excision of the joint, obtaining relief from pain at the cost of ankylosis. A knee which is solidly ankylosed in a position of 10 degrees to 15 degrees of flexion is painless and represents but a small handicap, and on the whole it seems the preferable alternative in the case of individuals in the third and fourth decades of life.

IV. SEPARATION OF THE UPPER EPIPHYSIS OF THE TIBIA

The injury is rare, and occurs between the ages of three and nine years. When displacement takes place, the epiphysis usually passes forward and

749

750

FIGS. 749 and 750.—Separation of the lower femoral epiphysis. (749) The corrected position is best maintained by the application of a plaster cast holding the knee in a position of acute flexion. (750) The cast should be immediately split on two sides as there is great danger of circulatory disturbances resulting from swelling.

laterally and the diaphysis backward and inward. Shortening and angulation may result at a later period from interference with the power of growth. After reduction under ether, there is not much tendency to redis-

751

752

FIGS. 751 and 752.—Lateral and anterior roentgenograms of epiphyseal separation of the lower end of the femur before reduction.

placement, and the injury may be treated, therefore, on a simple back splint. In difficult cases it will be necessary to fix the limb in plaster of Paris with the knee flexed to a right angle in order to relax the hamstring muscles, which otherwise tend to displace the diaphysis posteriorly. Massage may be begun at once and gentle movement at the end of a week.

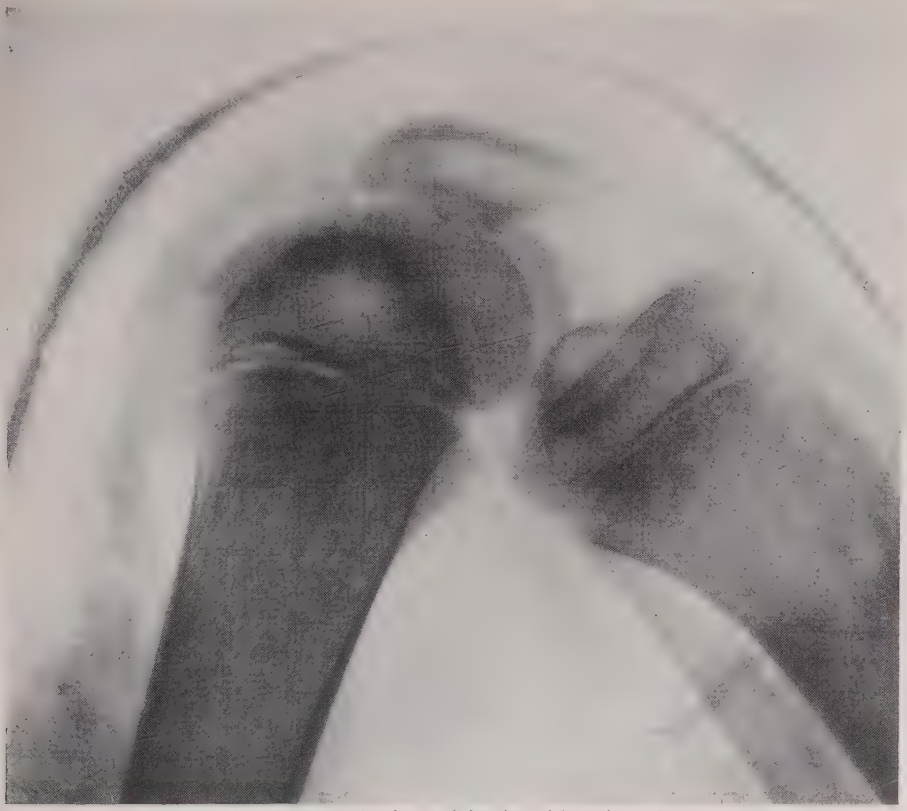


FIG. 753.—Same case following reduction and fixation of knee in position of acute flexion. (E. C. Cutler: Annals of Surgery.)

Occasionally the injury is complicated by an associated fracture of the tibial tuberosities and in such cases traction methods should be employed.

V. SEPARATION OF THE TIBIAL TUBERCLE

(Osgood-Schlatter Disease)

Occurrence.—Complete avulsion of the tubercle is rare, but slight separation is not uncommon. The latter condition occurs in the growing period before the epiphysis has become completely ossified, usually between the age of eight and fourteen years. At this period the strong pull of the quadriceps muscle falls on a weak cartilaginous attachment

and under the influence of unusual exertion or chronic strain the latter may easily give way. In a large number of instances this mechanical arrangement is still further weakened by the development of the tubercle as a separate centre of ossification, instead of as an outgrowth from the main epiphysis (Fig. 766).

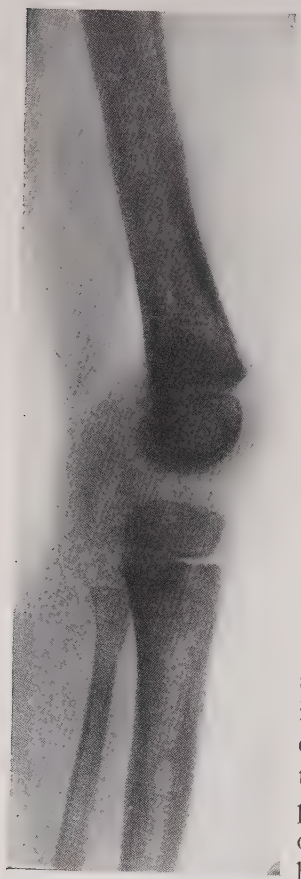


FIG. 754.—End result in case of compound separation of the lower femoral epiphysis one year after reduction. No interference with growth and perfect function of the knee. (Fracture Service, M. G. H.)

Diagnosis.— The separation is usually incomplete, but it is sufficient to cause interference with the extensor mechanism of the knee, the last few degrees of this movement being lacking on voluntary effort. The symptoms are rarely acute, the patient complaining of soreness over the tubercle, and weakness of the knee following a slight strain some time previous. On examination there is tenderness over the tubercle, and the limit of extension on active movement is slightly but definitely less than that on passive movement. In long-standing cases the tubercle is larger and more prominent than normal, due to the effect of chronic strain in stimulating bone production (Fig. 767).

Treatment.—It is usually possible to give prompt relief by the application of a crossed adhesive strapping to the tubercle and front of the knee, which holds the epiphysis down and relieves it of strain. Occasionally, when the pain is more acute, it is necessary to temporarily apply a plaster cast extending from the ankle to the groin, but even then weight-bearing may be permitted. The strapping should be reapplied every week for a period of two to four months, sometimes even longer before the union becomes solid.

VI. FRACTURE OF THE PATELLA

Fracture of the patella is a frequent injury. It occurs practically always in the period between twenty and fifty years of age, never in children and practically never in adolescents. It may be produced by either direct or indirect violence, and the injuries occasioned by each differ in type and usually require different methods of treatment.

Fracture by Direct Violence.— Fracture by direct violence is usually the result of a blow, as from the kick of a horse. It is rarely caused by a fall on the flexed knee as might be supposed, because in this position the weight is born on the tibial tubercle. The typical fracture of this type

is stellate, but it may be longitudinal or transverse (Fig. 768). It is usually comminuted and usually unaccompanied by much displacement because the lateral expansions of the quadriceps escape injury. The knee-joint is involved and is distended with blood.

Fracture by Indirect Violence.—Fracture by indirect violence may be produced either by muscular contraction alone or by a combination of muscle violence and forced flexion of the leg. Almost always the knee is

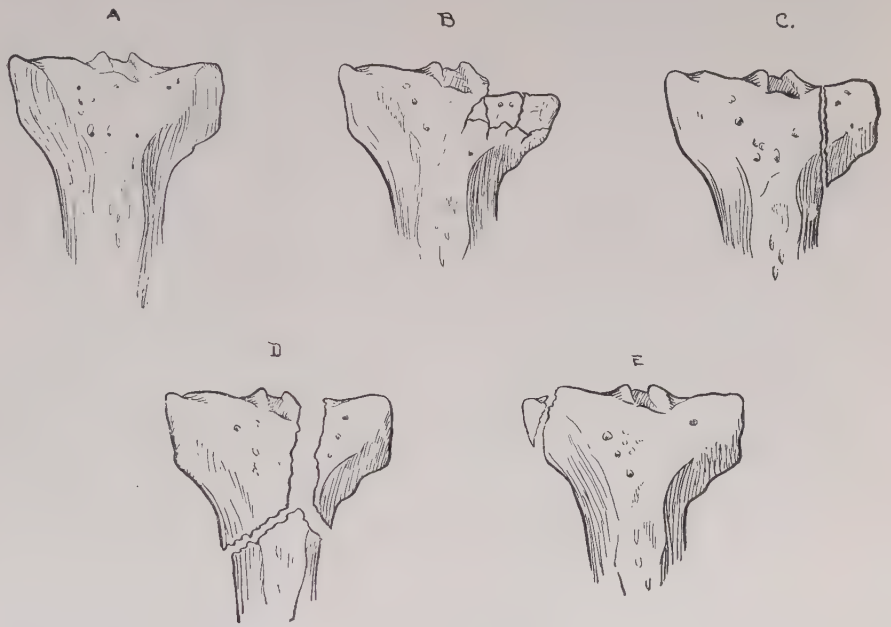


FIG. 755.—Fracture of the tuberosities of the tibia. (A) Normal tibia. (B) Comminuted fracture of outer tuberosity. (C) Vertical compression fracture. (D) Inverted "Y" fracture. (E) Avulsion fracture.

in semi-flexion at the moment of injury. In this position the patella is particularly liable to fracture, as only its upper portion is in contact with the femoral condyles, the remaining half or two-thirds projecting forward and downward totally unsupported. The lower end is fixed by the patellar tendon, while a fulcrum is provided at the upper end by the point of contact (Fig. 769). Contraction of the quadriceps muscle exerts a cross-breakage strain on the unsupported portion, with the result that the bone is snapped across transversely at about the junction of its lower and middle thirds. There is almost always an accompanying tear extending out on either side and involving both the capsule and the lateral expansions of the quadriceps. Depending upon the extent of this tear, a greater or lesser degree of separation of the fragments is permitted. The gap intervening between the fragments may vary from 2.5 to 7.5 cm. in width (Fig. 771).

Diagnosis.—The diagnosis rarely presents any particular difficulty if the patient is seen before an extreme degree of swelling has occurred. The description of the nature of the accident is important. The knee is found

756

FIG. 756.—Avulsion fracture of the outer margin of the external tuberosity. (Fracture Service, M. G. H.)

757

FIG. 757.—Vertical compression fracture of external tuberosity.

to be swollen and distended with fluid. If the fracture is of the comminuted type without displacement, the patella is soft and boggy to palpation and lacks the usual feeling of firm resistance. Crepitus and abnormal mobility may occasionally be demonstrated, and local tenderness is marked. Movement of the leg in extension, although possible, is usually too painful to be performed. If the fragments are displaced, as in the transverse type, the separation can usually be recognized and the extent

of the gap noted. In this type the extensor mechanism of the knee is destroyed and active movement impossible. Roentgenological examination confirms the clinical findings and demonstrates the nature of the fracture and the degree of displacement.

Treatment.—The indications for treatment are to secure approximation of the fragments and to relax the quadriceps muscle by fixation of the

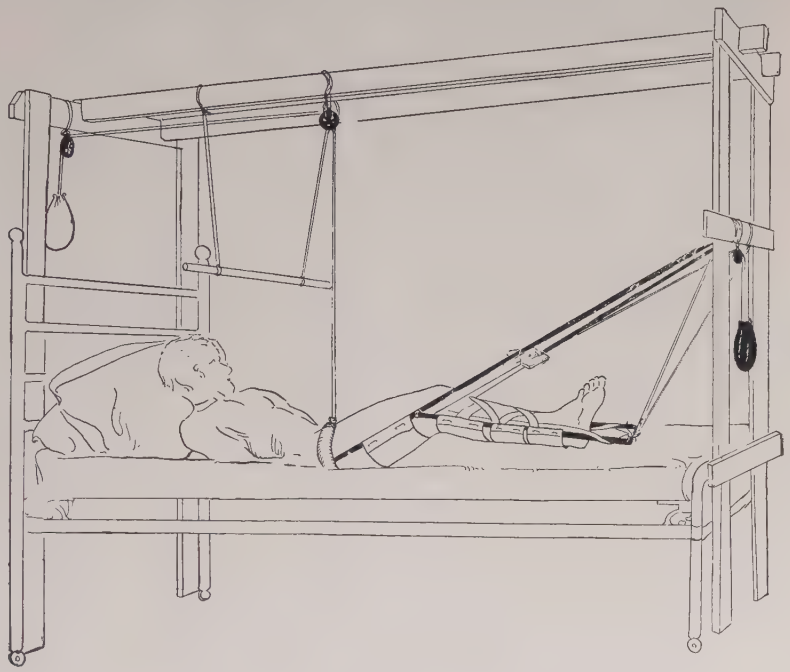


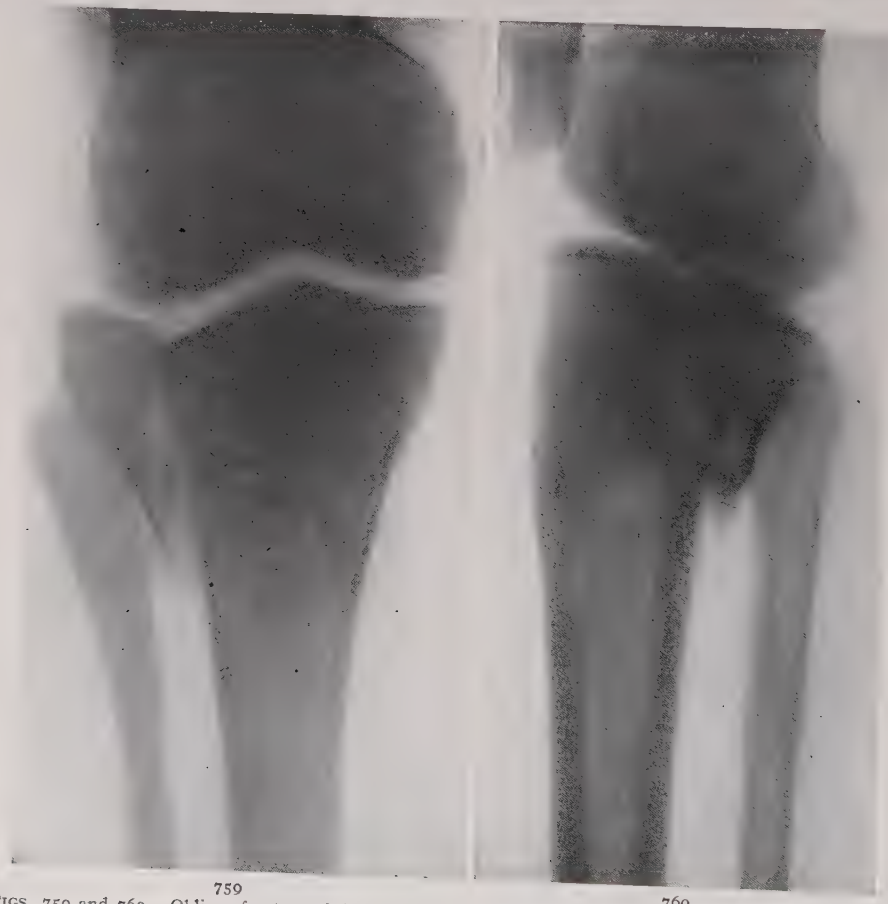
FIG. 758.—Drawing showing the method of applying the Thomas splint in fractures of the tuberosities of the tibia with separate extension bands to the thigh and leg.

knee in the extended position. In the case of fracture by direct violence these indications are easily met, as usually there is no displacement to be corrected. In the case of fractures with displacement, chiefly those resulting from indirect violence, the problem is complicated by the difficulty of obtaining accurate approximation of the fragments by external fixation alone.

Conservative Treatment in Fractures with Displacement.—In many instances, however, good function has resulted from conservative treatment by immobilization even when the gap between the fragments has persisted. It has been conclusively shown that the lateral expansions of the quadriceps muscle, through their insertion into the fascia of the leg, may undergo a vicarious development and replace the ruptured tendon to a large extent. If the gap between the bones is small, a bridge of scar tissue ultimately forms and functions satisfactorily. The period of dis-

ability is, however, long, the result uncertain, and the possibility of refracture through the fibrous bond great.

Advantages of Operative Treatment.—Exposure of the fracture by open operation with suture of the fragments is, on the other hand, a compara-



759 760

FIGS. 759 and 760.—Oblique fracture of the upper end of tibia involving the lateral and posterior margins. (Edinburgh Royal Infirmary.)

tively simple procedure and safe enough if a rigidly aseptic technic is used. By this method the knee-joint may be cleansed of the blood and fibrin contained within it, accurate approximation of the bony surfaces obtained, and the lacerations in the capsule and fibrous aponeurosis repaired. With proper after-treatment the period of disability can be greatly reduced and excellent end-results obtained.

Fibrous Union Versus Bony Union.—Greater experience with the operation and its results has led to its wider application. Thus it has been shown that with the non-operative method of treatment fibrous union

is the rule even in fractures without displacement. This is because the patella, being a sesamoid, develops in the middle of the tendon and lacks periosteum. Its anterior covering is composed of tendinous fibres, which shred out when fracture occurs and almost always turn down and become

Fig. 761.—Depressed fracture of external tuberosity and head of fibula. (Fracture Service, M. G. H.)

interposed between the fractured surfaces (Fig. 772). Fibrous union is always weak and exposes the patient to the danger of refracture, this accident occurring not infrequently. On the other hand, with the operative method of treatment the interposed tissue can be removed and accurate approximation secured, and this results in solid bony union in a large proportion of the cases.

Indications for Operation.—The present attitude of most surgeons is, therefore, in favor of operation in all cases where separation of fragments exists, provided that, in respect to age and general condition, the

patient is a good surgical risk. Operative treatment is on the whole more positively indicated when the patient's occupation is one demanding heavy rather than light physical effort, but in view of the modern improvement in surgical technic, with decreased risk of septic complications, this consideration seems less important than formerly.

Optimum Time for Operation.—Considerable discussion has hinged on

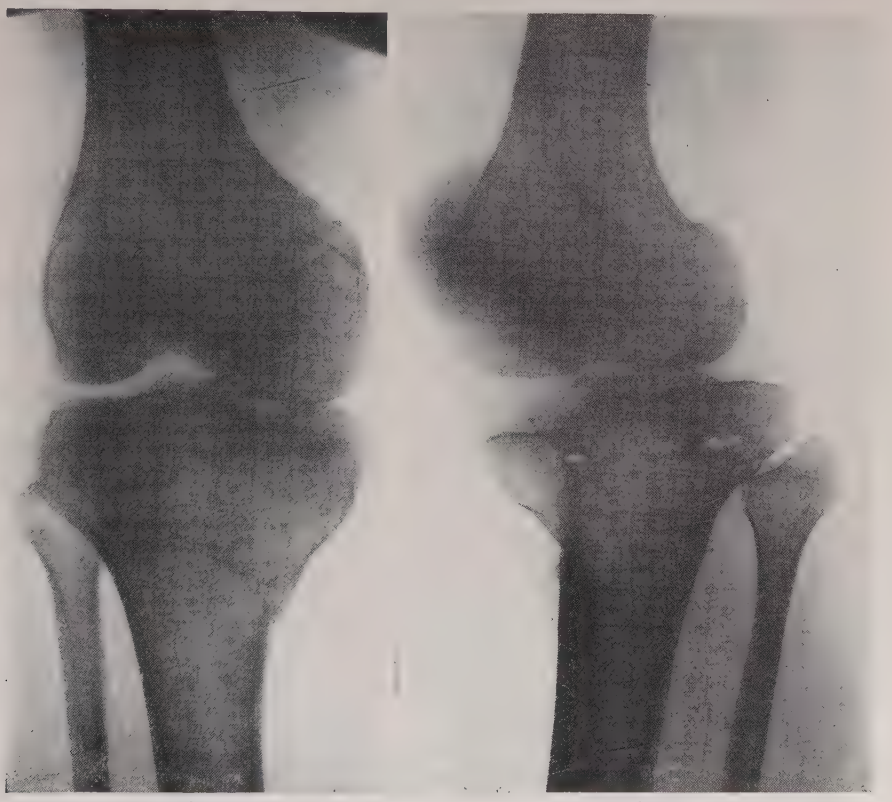
762

763

FIGS. 762 and 763.—Comminuted fracture of upper end of tibia associated with inward displacement of femur. (762) Before reduction. (763) Following open reduction and transfixion with bolt. (Fracture Service, M. G. H.)

the optimum time for operation. It has been considered by many that operation within the first week is more difficult because of the presence of blood and exudate, which obscure the structures to be repaired, and also that it is more dangerous because of the greater liability to infection, the ability of the tissues to resist bacterial invasion being temporarily diminished by the injury. At the end of five days absorption of the exudate is well under way, and the conditions are then supposedly more favorable for operation. However, considerations of this nature are usually inherited from surgical traditions and their origin may be traced back to a period when wound infection was a more frequent complication of operation than at present. Fracture of the patella is particularly the subject of surgical lore because it was one of the first fractures to be brought

within the scope of the operative method of treatment. In deciding upon the optimum time for operation in a given case the surgeon should be influenced chiefly by the local condition of the skin and the time required to adequately prepare it for operation. The surgeon who wishes to surround his patient with every possible safeguard will not hesitate to wait



764 765

FIGS. 764 and 765.—Impacted comminuted fracture of the tibial tuberosities, anterior and lateral views. (Fracture Service, M. G. H.)

a week or longer, if necessary, in order to obtain a clean operative field and one free from abrasions. Otherwise the operation may be performed with safety at any time.

Technic of Operation.—The operation itself consists in exposing the patella either by turning upward from below a semicircular flap of skin and subcutaneous tissue or by a direct vertical incision. Complete exposure of the aponeurotic tears must be obtained. The joint is inspected and sponged out with cotton swabs moistened with salt solution. Interposed tissue is removed from between the fragments and the fractured surfaces carefully approximated. Suture may be performed with wire or kangaroo

tendon, the general preference being for absorbable material. As a rule it is quite sufficient to stitch together the torn edges of the aponeuroses and the fibrous covering of the patellar fragments without drilling the bone (Fig. 773). Closure is without drainage. Immobilization is best obtained by the application of a plaster cast extending from the toes to the groin. When the patient is returned to his bed this may be suspended from

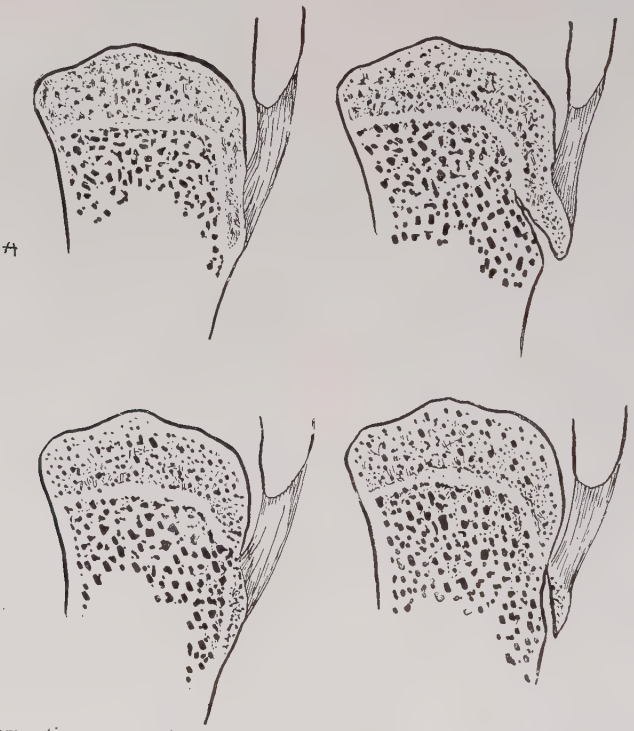


FIG. 766.—Diagrammatic representation of ossification of the upper end of tibia in relation to Osgood-Schlatter disease. (A) Normal ossification. (B) Ossification with separate centre for the tubercle.

an overhead frame with considerable advantage to his general comfort (Fig. 775).

After-treatment.—The after-treatment is of great importance. The plaster casing should be bivalved immediately. At the end of a week the anterior half is lifted and the stitches removed. Atrophy of the extensor muscles of the thigh and fixation of the patella must be prevented. Light massage of the anterior thigh muscles and passive movement of the patella, chiefly in the horizontal plane, are begun and repeated daily, the front of the cast being removed for this purpose and replaced afterward. At the end of two weeks massage may be permitted in the region of the knee. At the end of three weeks slight, passive movements by alternately raising and lowering the knee in the cast may be added to the program

(Fig. 776). At the end of four weeks the cast may be completely removed for short periods daily, and slight, active movements of the knee begun. At the end of five weeks the leg may be hung over the edge of the bed and active flexion and extension encouraged.

Protected weight-bearing may be permitted at the end of six or seven

Fig. 767.—Roentgenogram of Osgood-Schlatter disease.

weeks. A new bivalved plaster cast is applied extending from the ankle to the groin, and this is worn while walking to protect the patella from undue strain. It may be discontinued at the end of eight to nine weeks, and no further support should be necessary.

Non-operative Method of Treatment.—The non-operative or conservative method of treatment is particularly applicable in the case of fractures without displacement or in patients whose age and general condition render operation inadvisable or when suitable conditions for an aseptic operation are not at hand. The fragments are pressed as closely together

as possible and secured by adhesive strips applied above and below the edges of the patella (Figs. 780-783). The leg is snugly bandaged with flannel or woven elastic material and immobilized on a carefully padded Cabot posterior wire splint (Figs. 777-779) which is then suspended from an overhead frame. At the end of one week the dressing should be changed, the fragments pressed more closely together and a new adhesive strapping applied. A bivalved plaster cast extending from the ankle to the groin may be applied at the end of two to three weeks.

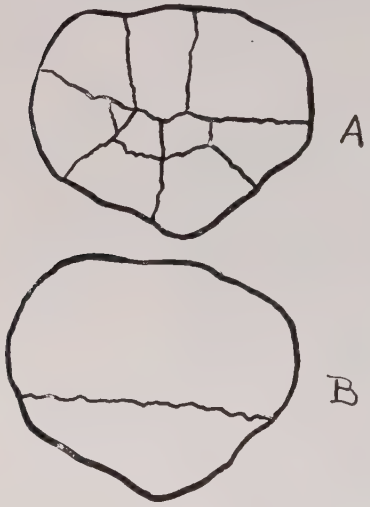


FIG. 768.—(A) Stellate type of fracture of the patella resulting from direct violence. (B) Transverse fracture of the patella resulting from indirect violence.

Massage of the anterior thigh muscles is begun at the end of one week and continued daily thereafter. At the end of four weeks the adhesive strapping about the knee is removed, and massage and mobilization of the patella instituted. At the end of six weeks active movements of the knee may be permitted. Weight-bearing with the plaster protective splint and crutches may be allowed at about the end of eight weeks. Protection of the knee by some form of apparatus is required for at least six months. A laced elastic knee-cap and canes may be substituted for the cast at the end of three months (Fig. 786).

VII. DISLOCATION OF THE PATELLA

Varieties.—Dislocation of the patella in other than an outward direction is a rare injury. Inward dislocation is the result of direct violence, as is also the vertical dislocation in which the patella rotates on its long axis, one of its lateral borders engaging between the condyles.

Outward Dislocation.—By far the most common variety is the outward dislocation in which the patella is displaced to the outer side of the lateral condyle. It usually first appears in early childhood and tends to recur and become habitual. It is usually the result of a combination of muscular violence and insecure anatomical arrangement of the knee.

Predisposing Causes.—Goldthwait[1] has pointed out that the quadriceps tendon is not directed in a straight line toward the insertion of the patellar tendon, but that its course is slightly oblique and that a slight angle with apex pointing inward is formed by its junction with the patella and patellar tendon (Fig. 784). Contraction of the quadriceps

[1] J. E. Goldthwait, *Boston Med. and Surg. Journ.*, February 13, 1904, p. 169.

muscle normally tends to displace the patella outward, but dislocation is prevented by the projecting margin of the external condyle which retains it in the trochlea. Slight anatomical variation, such as a low condylar ridge or an unusually long patellar tendon which allows the patella to ride above the trochlea even in flexion, or a condition of knock-knee which increases the angle between the quadriceps and the tendon of the patella tends, therefore, to weaken the retaining mechanism and predisposes to dislocation (Fig. 785).

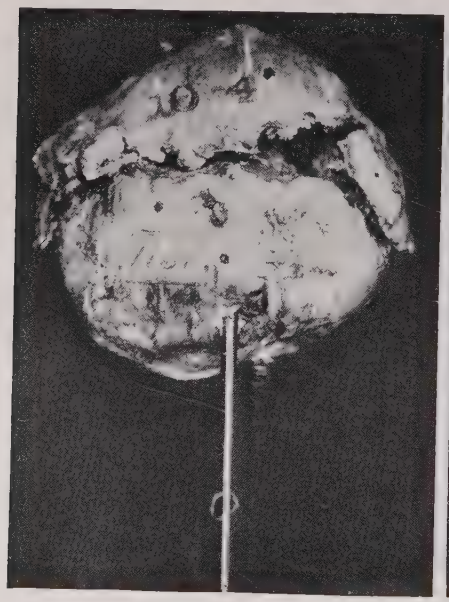
FIG. 769.—Mechanism of fracture of the patella by indirect violence. In semiflexion, only a small portion of the patella is in contact with the trochlea. Strain applied in this position tends to bend the patella across the femur and the transverse type of fracture results. (A) Showing relation of patella in semi-flexion. (B) How force is applied to cause fracture. (C) Wide displacement results from muscular retraction.

Recurrent Dislocation.—In persons with recurring dislocation of the patella the presence of one or all of the above abnormalities may almost invariably be demonstrated. The original dislocation usually appears in early childhood and may occur as the result of slight violence but more commonly is produced by muscular contraction alone. After recurring several times, the instability increases and may become so great that the patella is dislocated every time the knee is flexed, or it may become permanently displaced to the outer side of the condyle. A congenital type of dislocation is also recognized, the displacement being of a permanent type. Such cases may be attended by surprisingly little disturbance of function.

Single Traumatic Dislocation.—In other cases, where the underlying mechanical weakness is less marked, the childhood period may be passed without accident, and the dislocation may appear in adult life as the result of a fall with abduction of the knee or from direct trauma. While recurrence may not occur in these cases, the knee should be protected for a considerable time in order to diminish this possibility.

Diagnosis.—The diagnosis is readily made from inspection and palpation if the patient is seen while the patella is still displaced. Often the patient or his friends make the diagnosis before the physician's arrival. In the recurring form the patient is usually aware of the nature of the injury and may be able to reproduce the dislocation for the purpose of demonstration. This, however, is rarely advisable, as the diagnosis can be made from the patient's description of the trouble.

Treatment of Simple Traumatic Dislocations.—Treatment of the simple traumatic dislocations in adults is chiefly a matter of reduction and prolonged immobilization. Reduction is accomplished by extending the knee and flexing the hip in order to relax the quadriceps. The patella may then be disengaged and lifted over the condylar ridge. Immobilization is obtained by a plaster of Paris cast extending from the ankle to the groin,



770

FIG. 770.—Specimen of transverse fracture of the patella. (Warren Anatomical Museum.)

771

FIG. 771.—Old transverse fracture of the patella with fibrous union. (Warren Anatomical Museum.)

the knee being held in the position of complete extension. Weight-bearing in the plaster may be permitted at the end of one week. The cast should be bivalved, and voluntary movement of the knee, the patella being supported manually on its outer side, permitted after two weeks. The cast should be worn for one month and is then replaced by a laced elastic knee-cap (Fig. 786) or a flannel bandage with felt strips placed on the inner and outer border of the patella, which should be worn until the end of three months. Elevating the inner border of the heel 6 mm. also gives additional protection by tending to correct the inward angulation of the knee.

Operative Treatment of Recurrent Dislocations.—Cases of recurrent or habitual dislocation require operative treatment. Many operations have been devised, all of which aim at correction of the underlying cause of the mechanical weakness. Thus Goldthwait transplants the outer half of the patellar tendon downward and inward to the inner border of the tibia,

or the entire tubercle may be transplanted. Brackett splits and elevates the outer margin of the anterior surface of the external condyle. Gallie uses transplanted tendon or rolled-up fascia to form a restraining ligament extending from the patella to the mesial surface of the inner condyle. All of these operations are satisfactory when properly selected for the individual patient, but in the average case the Goldthwait operation is usually best on account of its simplicity and the small risk entailed to future function of the knee. Immobilization in plaster with the patient recumbent for six weeks is required for a successful result.

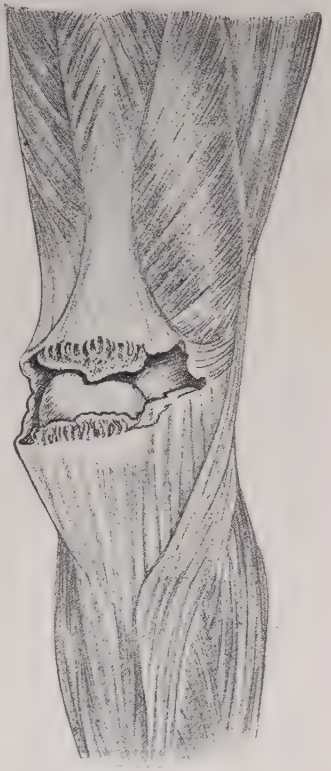


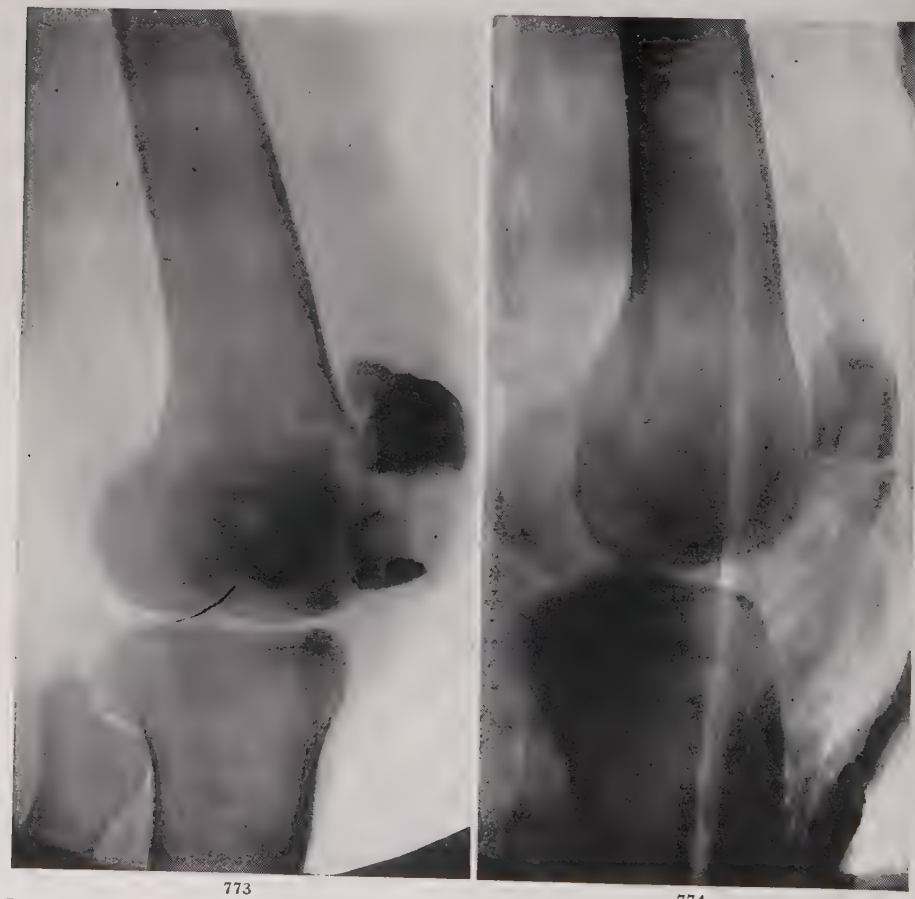
FIG. 772.—Drawing of transverse fracture of the patella, showing the tear in the capsule and lateral fibrous expansions of the quadriceps extensor, also the frayed-out edges of the tendon turned downward between the fragments.

VIII. DISLOCATION OF THE KNEE

Pathology.—Dislocation of the knee is a very uncommon injury and requires for its production a severe type of violence, such as a blow on the knee or leg from an automobile collision, or leverage strain from the engagement of the leg in the rotating wheel of an engine, or forcible hyperextension of the knee from falling into a hole while running. Both on account of the nature of the violence and the superficial situation of the bones, the injury is often compound. The dislocation is accompanied by a rupture of the crucial, the internal and external lateral, and the posterior ligaments, and in addition the injury may involve the strong supporting tendons of the hamstring muscles or cause damage to the popliteal vessels and nerves. Gangrene or paralysis of the leg results not infrequently, and amputation has been frequently necessitated.

Varieties.—Anterior, posterior, mesial, lateral, and rotary types of dislocation have been distinguished, the terms being used to describe the position of the leg with reference to the femur. Luxation occurs with nearly equal frequency in either the antero-posterior or lateral planes, the rotary variety being least common (Fig. 788). It may be complete or incomplete. The anterior dislocation results from forced hyperextension of the knee, the posterior one from the application of force to the front of the leg in a backward direction, while the mesial and lateral varieties are produced by violent abduction or adduction of the leg.

Diagnosis.—The diagnosis presents but little difficulty in the case of complete dislocations, the gross nature of the displacement being apparent from a glance at the leg. Incomplete luxations are less readily recognizable, as the abnormal relation of the bones may be obscured by



773 774

FIGS. 773 and 774.—Fracture of the patella. (773) Before reduction. (774) Following open reduction and suture. (Fracture Service, M. G. H.)

swelling. Extreme abnormal mobility is usually demonstrable. Roentgenological examination is necessary to eliminate the possibility of associated fractures of the articular margins or of the tibial spine. The examination should never be completed without carefully testing the condition of the vessels and nerves distal to the seat of the injury.

Reduction and Fixation.—Because of the extensive injury to the ligaments and muscles, but few structures are left intact to resist reduction,

and replacement is readily accomplished by traction on the leg with appropriate pressure on the tibia and counter-pressure on the femur. Following reduction the knee should be immobilized in a position of about 30 degrees flexion, this being the best position to secure relaxation of the ligaments and also affording the most useful function in case of ankylosis.

FIG. 775.—Fracture of the patella. Bivalved plaster casing used after open reduction and suture. Suspension of the cast is an important item in protecting the fracture line and also in adding to the comfort of the patient. (Fracture Service, M. G. H.)

Fixation is obtained by the application of a plaster casing extending from the toes to the groin. The plaster should be immediately bivalved, as extensive swelling is to be expected.

After-treatment.— Fixation should be maintained for a long period if a useful knee is to be the result. Stiffness and limitation of movement are less to be feared than abnormal mobility and instability of the joint. A period of six months to a year may be necessary to obtain strong healing of the ligaments, but the surgeon should be guided in this by examination of the knee at different intervals. The reported cases of good functional recovery have always been those that were immobilized the

longest, and the necessity of prolonged fixation cannot be too much emphasized. Weight-bearing in a plaster cylinder extending from the ankle to the groin may be permitted at the end of one month and protected use throughout the remaining period of treatment is an aid to healing.

Operative Treatment.—Operative treatment is of little value in the fresh dislocation because of the impossibility of repairing the extensive

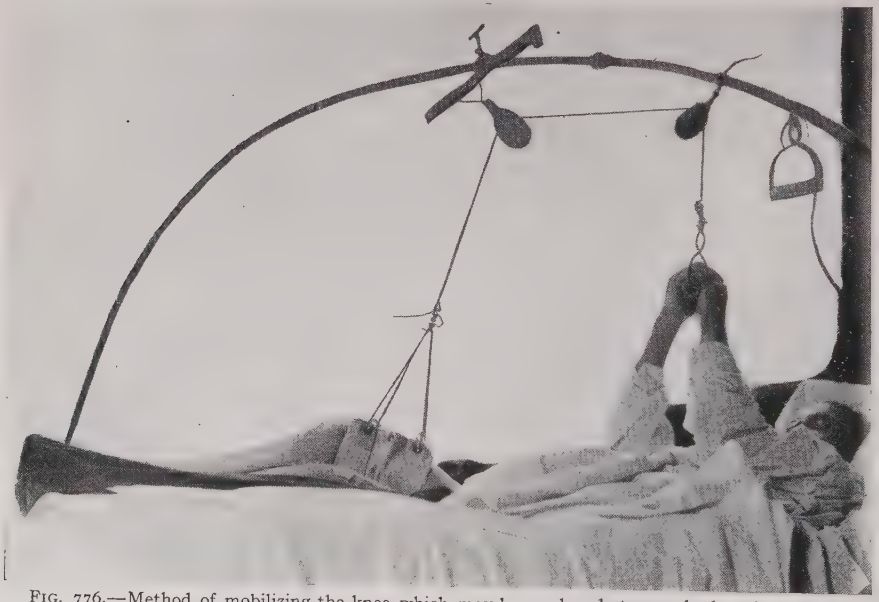


FIG. 776.—Method of mobilizing the knee which may be employed at an early date following operative treatment of fracture of the patella. When the pull on the knee is released, the knee sinks back into the posterior section of the cast. (Fracture Service, M. G. H.)

injury. At a later period removal of the semilunar cartilages, in case they have been displaced, or the insertion of fascial ligaments to replace those which have been torn, may be indicated, depending upon the difficulties which may be encountered when fixation is finally discontinued. In the presence of a compound dislocation, an effort should be made to save the leg by immediate débridement. In all cases except those with very small wounds this will probably necessitate complete excision of the articular surfaces in order to entirely remove the contaminated and traumatized tissues. However, a knee which is solidly ankylosed in a position of 15 degrees to 20 degrees of flexion represents but a small handicap and is preferable to the weak, painful, and wobbly knee which may result from a simple, uncomplicated luxation.

IX. INTERNAL DERANGEMENTS OF THE KNEE-JOINT

Classification.—Injuries of the lateral ligaments, the semilunar cartilages, the crucial ligaments, the tibial spine, and the infrapatellar pad of fat are responsible, with loose bodies, for most internal derangements of the knee-joint. J. K. Surls and R. B. Osgood,[2] in a series of 181 operated cases for such derangements, give the following order of frequency as obtained from the records of the Massachusetts General Hospital between the years 1900-1920:

Internal semilunar	43.1%
External semilunar	8.3%
Loose bodies	22.7%
Hypertrophic fringes	13.8%
" fat pads	5%
" bone	2.8%
Crucial ligaments	1.7%
Fibrous bands	1.7%
Chronic arthritis	1.1%

Etiology.—Severe twisting forms of violence, sustained by the knee when flexed and slightly abducted and with the foot fixed, cause injury of the internal lateral ligament, the internal semilunar cartilage, the crucial ligaments, and the tibial spine. The sudden torsion responsible is nearly always a rotation outward of the tibia upon the femur. This is possible only when the knee is flexed, because then the lateral ligaments and anterior crucial ligaments are no longer taut and thus allow rotation. Less frequently direct trauma may cause injury to the crucial ligaments and spine of the tibia. Sometimes it may be combined with a severe twist of the knee made by the patient to save himself from falling. Torsion and direct trauma also produce the majority of derangements of the external semilunar cartilage. Internal derangements of the knee-joint are met with much oftener in males than in females (10:3, Osgood and Surls). They occur in young and middle-aged adults who engage in vigorous athletics such as football, and in those whose occupation throws a strain on the knee: for example, coal miners. Out of 500 consecutive cases of injuries and displacements of the semilunar cartilages reported by Martin[3] of Newcastle, 62 per cent. were in coal miners and 20 per cent. in footballers.

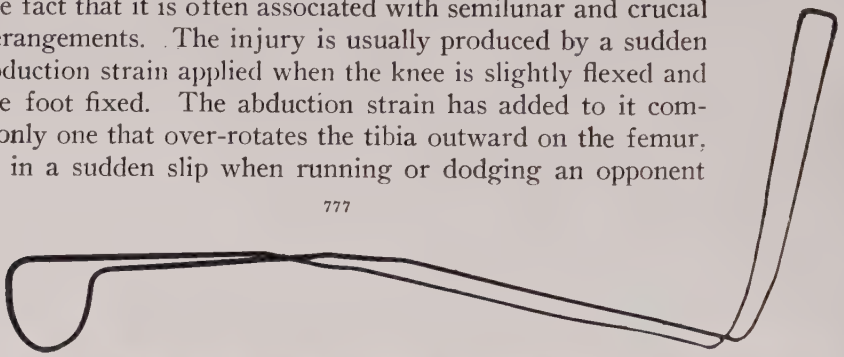
I. INJURY OF THE LATERAL LIGAMENTS

Mechanism and Pathology.—The internal lateral ligament is much more frequently involved than the external. Injury of the former, whether

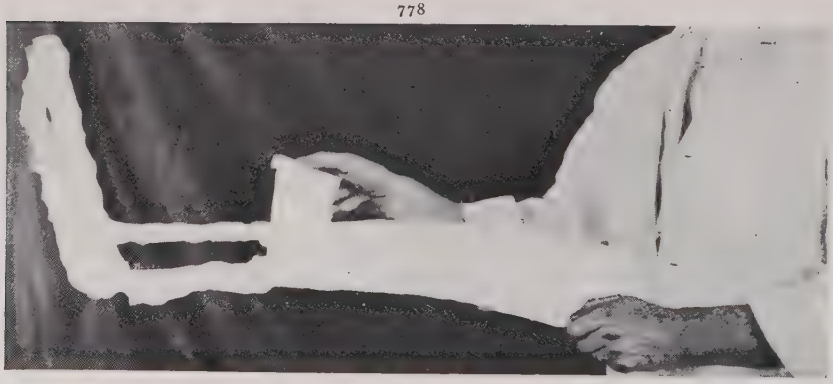
[2] J. K. Surls and R. B. Osgood, *Journ. Bone and Joint Surg.*, October, 1923, p. 635.
[3] A. M. Martin, *Lancet*, October 19, 1912.

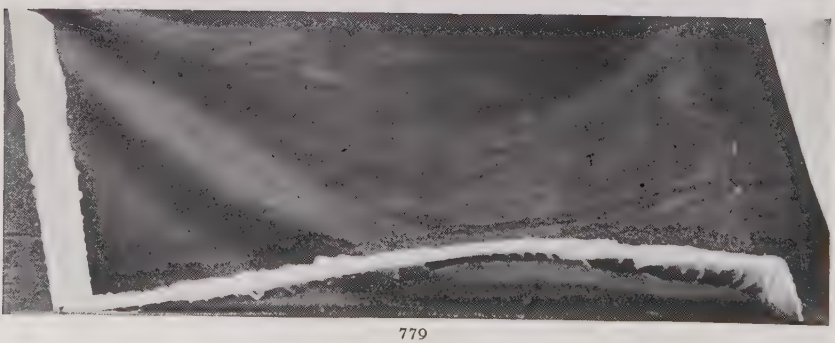
it results in stretching or in an actual rupture, derives special importance from predisposing the internal semilunar cartilage to injury and from the fact that it is often associated with semilunar and crucial derangements. The injury is usually produced by a sudden abduction strain applied when the knee is slightly flexed and the foot fixed. The abduction strain has added to it commonly one that over-rotates the tibia outward on the femur, as in a sudden slip when running or dodging an opponent

777



778





779

FIGS. 777, 778 and 779.—Cabot posterior wire splint. (777) Splint itself. (778) The splint is prepared by winding it with cotton padding and covering it with bandage. (779) The splint ready for application.

at football or in miskicking the ball. In nearly all cases there is the flexed and abducted knee, the fixed foot and the rotation of the body inward. The whole ligament may be stretched in its superficial and deep fibres, or the deep fibres may be torn across at their point of attachment to the femur or tibia. In so doing they may avulse a sliver of bone, pro-

ducing a " sprain-fracture," discoverable by a roentgenogram. The fibres which attach the internal semilunar cartilage at its periphery to the internal lateral ligament may or may not be torn and it is important to try and settle this point in diagnosis.

Diagnosis.—Sudden and severe pain is experienced in the knee in the line of the internal lateral ligament and sometimes the sensation of something giving way. The pain does not pass off and is quickly followed by effusion. The swelling fills up the hollows on either side of the patella and raises the patella from the femur—" floating patella." If the internal lateral ligament is torn across at its tibial or femoral attachment—more commonly the former—local tenderness is present at the site of the tear, which it will be noticed is below or above the actual level of the joint. If the point of maximum tenderness is situated in the line of the ligament at the actual level of the joint, it is reasonable to suppose that the deep fibres which give attachment to and anchor the periphery of the internal semilunar cartilage have been torn and point the way to more inclusive treatment of the disability. In uncomplicated injury of the internal lateral ligament no history of blocking is forthcoming and the symptoms are less severe than in injury of the internal semilunar cartilage. The pain is made worse by attempted passive abduction at the knee and there may be hypermobility in this direction. To complete the examination, the stability of the joint should be tested in the antero-posterior plane to exclude injury of the crucial ligaments, and finally a roentgenogram should be taken (Figs. 791 to 793).

Treatment.—A recent rupture of the internal lateral ligament will heal entirely if protected from strain until it regains its tone. The process of healing is slow and overstretching can occur very easily. In recent severe cases of sprain of the knee the patient must be put to bed and firm pressure applied by cotton wool and a bandage. Once or twice a day the joint may be exposed for massage and graduated movement to promote absorption of the effusion and prevent the formation of adhesions. It may also receive hot and cold douching. If the effusion does not clear up readily or if it is under considerable tension, aspiration is indicated. When some of the fibres of the internal lateral ligament are torn, immobilization must be practised until healing is complete (4-6 weeks) and then active use is begun with protection against strain, by elevating the inner border of the heel six mm. In more severe cases, a knee-cage (Fig. 794) must be worn for eight weeks, with limitation of the last fifteen degrees of extension of the joint. In cases of complete rupture, immobilization in a plaster of Paris case from ankle to groin must be employed for three to four months, the knee being almost completely extended until lateral mobility disappears. A knee-cage is then worn for two months, the inner border of the heel being also elevated.

The very great importance of treating minor derangements of the knee with great care when they first occur should be insisted upon, as it is the neglect of a proper period of fixation and protection that so often leads to prolonged, progressive and recurrent disability. A form of

780

781

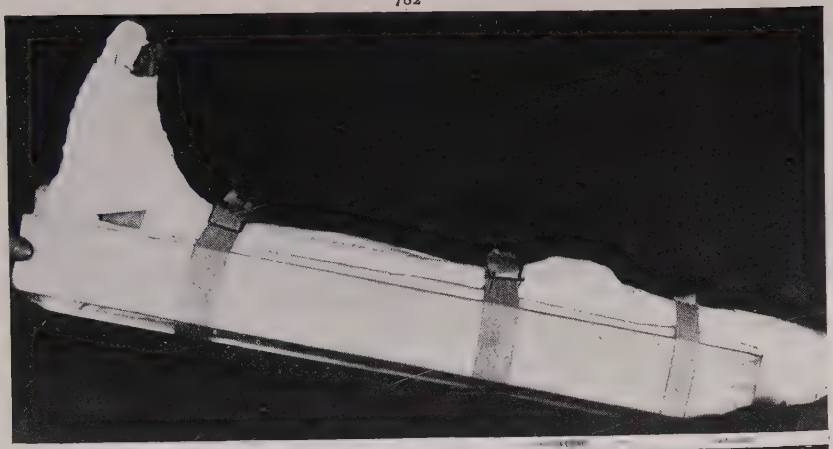
FIGS. 780 and 781.—Fracture of the patella. Application of the Cabot splint. The padding is applied in such a way as to lift the foot and prevent pressure on the heel. The splint is retained in position by the application of bandage and the fragments of the patella are drawn toward each other by the application of adhesive strips as shown.

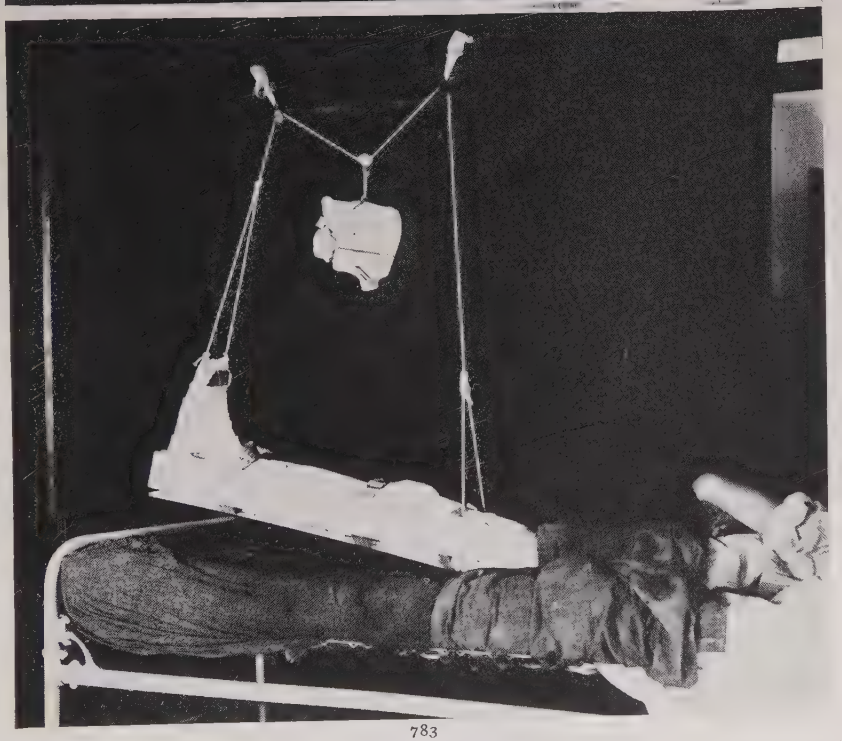
vicious circle is easily established, in which there is increased liability to strain and decreased power of recovering from it. Not only does an overstretched internal lateral ligament produce joint instability *per se*, but by leading to recurrent attacks of effusion (traumatic hydrops), and to relaxation of all the ligaments, and, more important still, by causing reflex and progressive atrophy of the quadriceps muscle, it opens the pathway for injury, from minor forms of trauma, to other structures it is designed to protect: namely, the internal semilunar cartilage and the crucial ligaments.

2. INJURIES OF THE SEMILUNAR CARTILAGES

Causation.—Undue mobility, displacement or actual fracture are the injuries which may be sustained and they affect the internal semilunar

782





783

FIGS. 782 and 783.—Fracture of the patella. Application of the Cabot splint. Side splints are then applied and held in place by buckle straps. The splint may be suspended from an overhead frame, as shown, both for the sake of comfort and also because this secures additional relaxation of the quadriceps.

much more commonly than the external (9:1, Jones[4]). The condition is an important one from its frequency and from the standpoint of correct diagnosis. It is met with in those who engage in athletics, particularly football and tennis, or those who follow occupations, such as coal mining, which entail working in a squatting or kneeling position for long periods. In low working seams the miner has to use his pick and shovel in this position, and from the nature of the work it is the left knee that is more commonly affected, since sudden movements are usually from right to left. The internal lateral ligament and the coronary or "suspensory" ligament are gradually stretched. The cartilage becomes less securely anchored at its periphery and is liable to be displaced toward the centre of the joint by some sudden movement which combines flexion and abduction of the knee with internal rotation of the femur inward on the tibia, the foot being fixed. Such an action comes into play when the miner rises suddenly from the squatting position and throws the coal over the left shoulder. Sometimes the inner side of the knee is struck while the man is squatting, producing violent abduction of the leg and outward rotation of the tibia, and to save himself from falling the man rotates his body inward, suddenly extends the knee, and nips the cartilage between the articular surfaces.

FIG. 784.—Recurrent dislocation of the patella. The line A-B represents the direction of the quadriceps extensor muscle. B-C represents the line of the patellar tendon. It will thus be seen that A-B-C forms an angle whose apex is directed inward and that contraction of the muscle tends to displace the patella outward. (D) represents the point to which the patellar tendon should be transplanted to correct this tendency.

Mechanism and Pathology.—The combined flexion and abduction of the knee opens up the inner compartment of the joint, and the internal semilunar cartilage, in its movement backward during flexion, slips under the femoral condyle and gets jammed between the femur and tibia when the knee is suddenly extended. When external rotation of the tibia on the femur takes place, the anterior part of the cartilage approaches the intercondyloid notch and if it gets too near, the sudden extension of the knee causes the free border of the cartilage to be caught. A common lesion seen at operation is one in which a portion of the inner edge of the anterior extremity of the cartilage projects as a tag towards the centre of the joint. If such catching takes place and the cartilage retains its peripheral attachment, then the cartilage is liable to be torn across. A definite

[4] R. Jones, *British Med. Journ.*, August 5, 1916.

pull is exerted on the peripheral attachment and as a result of this, the anterior part of the cartilage which is farthest away from this point may be torn away or a longitudinal splitting occur in the anterior extremity of the cartilage. If the anterior end of the cartilage does not give way when the free border is nipped and if the peripheral attachment remains intact, the cartilage usually splits longitudinally in its middle part and the inner crescent passes in between the condyles and may rest against the crucial ligaments—the "bucket-handle" split. Less commonly the posterior extremity is dislocated. Undue mobility of the cartilage from separation of its peripheral attachment is probably the most common and least severe of the affections of the cartilage. Locking may or may not result from inability of the cartilage to move peripherally when the knee is extended, but it is not until a second injury occurs which lacerates the cartilage, that operation is usually undertaken.

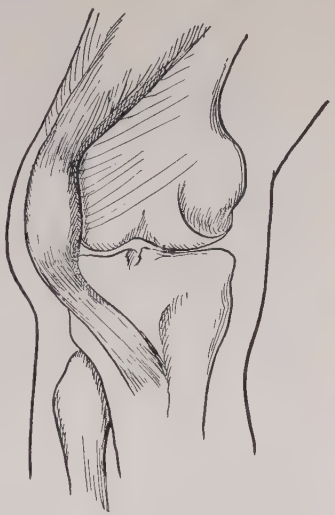


FIG. 785.—Diagrammatic representation of luxation outward of the patella.

Injury of the External Semilunar.— The mode of production of injuries of the external semilunar cartilage is not so clear, but doubtless is somewhat similar. Phemister [5] and others have described the presence of cysts of the external cartilage, associated with these injuries. An anatomic explanation for the much greater frequency of lesions of the internal semilunar cartilage as compared to those of the external cartilage lies in the smaller range of movement allowed in the former. The internal cartilage has extensive peripheral attachment and its extremities lie further apart. Thus the internal semilunar has a smaller margin of safety when the knee is pushed beyond its normal limits of motion. Again, the preponderance of inward torsions of the femur over outward ones, on the part of the athlete and worker, provides a physiological explanation of the same thing.

Diagnosis.— A thorough knowledge of the modes of production of such derangements is necessary in diagnosis, because a great deal depends on the history of the accident. Very little may be discovered by physical examination when the patient does not present himself until several weeks after the injury.

Recent Injuries.—When seen immediately after injury, there is usually a history that while making a sudden movement in dodging, running, jumping, or kicking a football, or in rising from a squatting position, the

[5] D. B. Phemister, *Journ. A. M. A.*, March 3, 1923, p. 593.

patient was seized with very severe sickening pain in the knee, with sometimes the statement that something was felt to give way in the knee. He may fall to the ground and be unable to rise or put his foot to the ground. On examination the knee is found to be held in slight flexion, and passive attempts to extend it are both painful and unsuccessful. Local tenderness may be elicited by making pressure on the joint-line, at a point midway between the internal ligament and ligamentum patellæ. Effusion rapidly takes place. Occasionally a tender projection or thickening which represents the tip of the displaced cartilage may be felt protruding in the inter-articular line.

FIG. 786.—Laced elastic knee-cap useful in the convalescent treatment of various types of knee injury.

Old Injuries.—Old-standing cases complain of recurring attacks of locking coming on suddenly from slight twists of the knee, accompanied by pain and swelling. The locking is usually transitory and responds favorably to some manœuvre, discovered by the patient himself, to extend the knee and unlock the joint. Examination is often negative but there may be present local tenderness over the anterior extremity of the cartilage. The quadriceps extensor shows definite atrophy. Distinction between lesions of the external and internal semilunar cartilages is based on the mechanism of the injury and reference of the symptoms to the outer or inner side of the knee. Differentiation of internal semilunar derangements from sprain or rupture of the internal lateral ligament is arrived at by the different situations of the areas of maximum tenderness (Fig. 796). In the case of a loose body, the site of the pain varies and sometimes the body itself can be palpated. Hypermobility in the antero-posterior plane is tested to exclude crucial injury. A roentgenogram excludes the presence of a loose body and of bone injury. A positive diagnosis of a lesion of the internal semilunar cartilage itself can frequently be made from the roentgenogram, which shows a faint indistinct shadow between the joint surfaces, present on the affected side but not on the other. Stereoscopic views of both knees should be taken. Bircher has practised

the taking of roentgenograms after inflation of the joint with oxygen or nitrogen gas and reports eight positive findings of internal semilunar injury in nine cases examined and confirmed at operation.

In some cases of mobile or torn semilunar cartilage it is difficult to determine whether the cartilage has been completely reduced. Such cases may be able, apparently, to extend the knee, but in cases of continued displacement, it will be found that the affected leg lacks a few degrees of

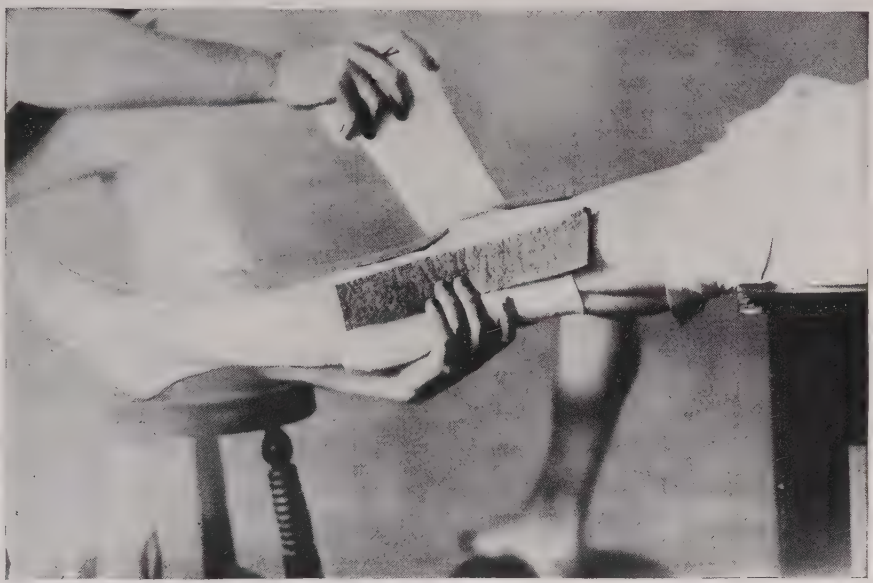


FIG. 787.—Method of protecting the knee by a soft flannel bandage reinforced with felt strips. This is useful in recent minor injuries of the knee, also in the convalescent treatment of more severe injuries.

complete extension as compared with its fellow of the opposite side. Passive hyperextension and weight-bearing are painful.

Reduction.—In case displacement still exists, reduction should be attempted. The Jones method is effective and may be attempted without an anæsthetic. With the patient lying on his back the surgeon stands on the affected side facing toward the head. The patient is requested to completely flex the hip and knee, which he can usually do without pain. The surgeon grasps the foot with one hand, while the other hand is placed on the outer side of the knee (Fig. 797). The surgeon externally rotates the leg and counts one, two, three. On the count of three the patient vigorously kicks the leg out into extension, the external rotation being maintained by the surgeon, and replacement occurs during the movement. If this fails, manipulation of the knee should be performed under an anæsthetic, the knee being flexed and extended with the leg externally rotated. The test of reduction is the ability to completely extend the knee, and in case of failure operative removal should be advised.

After-treatment.—Following reduction the leg should be immobilized in a plaster cast extending from the ankle to the groin, with the knee flexed to a few degrees for comfort. The cast may be split at the end of ten days and massage of the thigh muscles and knee begun. Fixation should be maintained for a month, when an elastic bandage may be substituted and

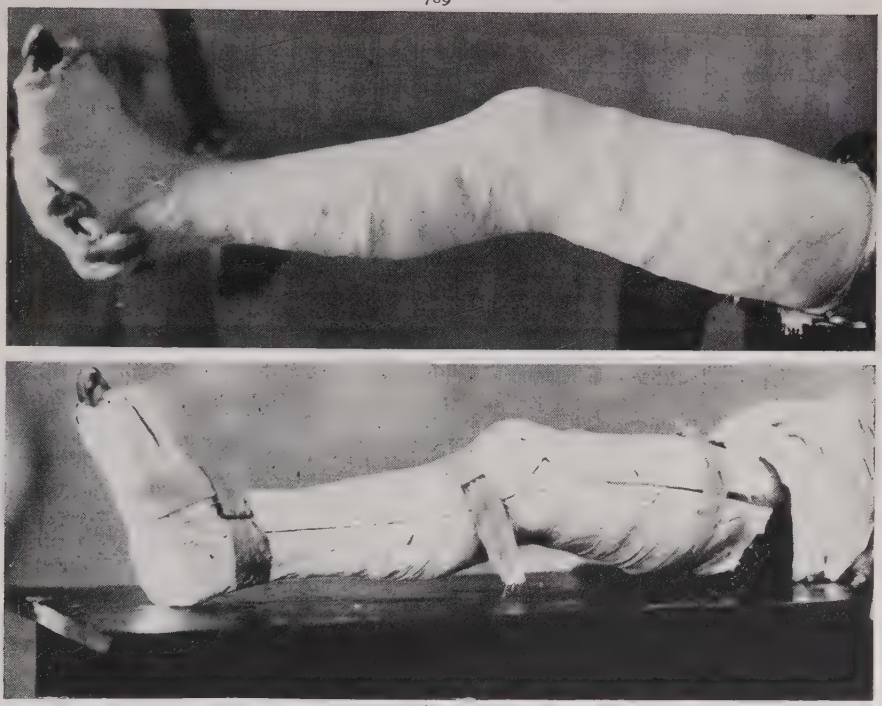
FIG. 788.—Dislocation of the knee. (A) Posterior luxation. (B) Anterior luxation.

active weight-bearing permitted. Additional protection is afforded by elevating the edge of the heel six mm. on the affected side.

Excision of the Cartilage.—In case of recurrence of the displacement, operative removal of the offending cartilage should be advised. Rigid asepsis is necessary. Exposure is obtained by a small "J"-shaped incision extending vertically downward over the front of the cartilage and then curving inward or outward away from the patella along the upper margin of the tibia. The cartilage is dissected away and removed well back of the middle. The wound is carefully closed in layers. No fixation is required beyond that obtained by a voluminous dressing. Crutches may be permitted at the end of one week, partial weight-bearing at the end of two weeks, and, if a careful technic has been followed, recovery should be nearly complete at the end of three weeks.

Operative treatment should never be advised following the original injury unless all efforts at reduction have failed. Many surgeons prefer to try conservative treatment even after the second attack. If further trouble is encountered, however, the cartilage should be removed, as displacement will recur from time to time and greatly hinder the patient's

789



790

FIGS. 789 and 790.—Dislocation of the knee. (789) Cast applied, holding the knee in moderate flexion and the foot at right angle. (790) Cast should be immediately split on two sides and retained in position by bandage, as great swelling is to be expected.

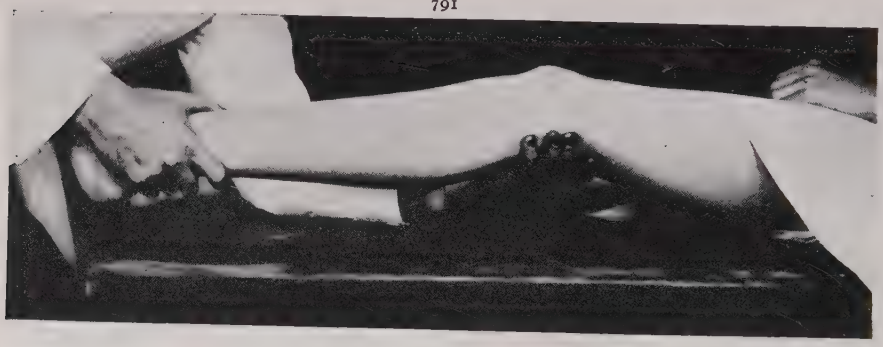
activities. As a matter of fact, if this accident occurred while the patient was crossing a busy thoroughfare it is easy to understand that it might actually endanger his life.

3. INJURY OF THE CRUCIAL LIGAMENTS

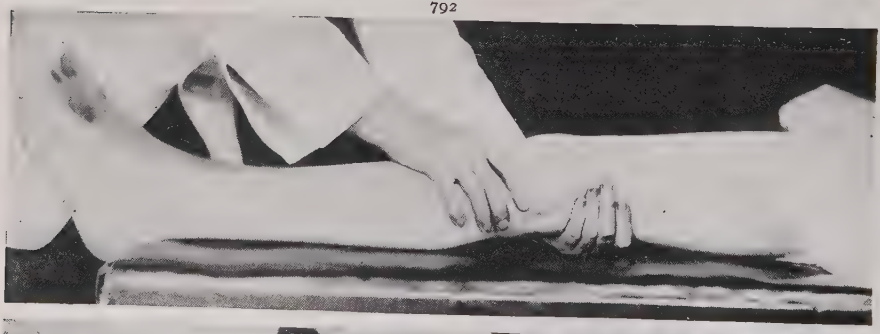
Mechanism and Pathology.—The crucial ligaments are injured much less frequently than the lateral ligaments, and the anterior crucial is the one more commonly affected. The chief function of the crucial ligaments is to maintain the stability of the knee in the antero-posterior plane; they also aid in lateral stabilization, but clinically this function is less important. When the knee is slightly flexed, the anterior crucial takes a certain amount of abduction strain. They also limit internal rotation of the knee. The

anterior crucial is injured by forcible hyperextenson and hyperabduction strains of the knee. The latter is similar in type to the kind of violence

791



792



793

FIGS. 791, 792 and 793.—Method of examining the knee to detect injury of the ligaments. (791) Testing for abnormal lateral mobility of the knee such as would indicate injury of one of the lateral ligaments. (792) Testing for abnormal mobility in the antero-posterior plane with the knee extended. When present, this denotes injury of the anterior crucial ligament. (793) Testing for abnormal mobility in antero-posterior plane with the knee flexed. When present, this indicates rupture of the posterior crucial ligaments.

which injures the internal lateral ligament and internal semilunar cartilage: namely, sudden rotation of the body inward upon the fixed foot, with the knee flexed and abducted. First, the internal lateral ligament stretches or

ruptures, the peripheral attachment of the internal semilunar cartilage is torn, and then the strain continuing to operate, the anterior crucial ligament is stretched or torn. Partial or complete avulsion of the tubercle of the tibial spine which gives attachment to the ligament may also occur. Rupture of the posterior crucial ligament is usually produced by sudden posterior displacement of the tibia on the femur when the knee is flexed. Rupture of the anterior crucial ligament seems to involve the femoral attachment more frequently than the tibial one, and

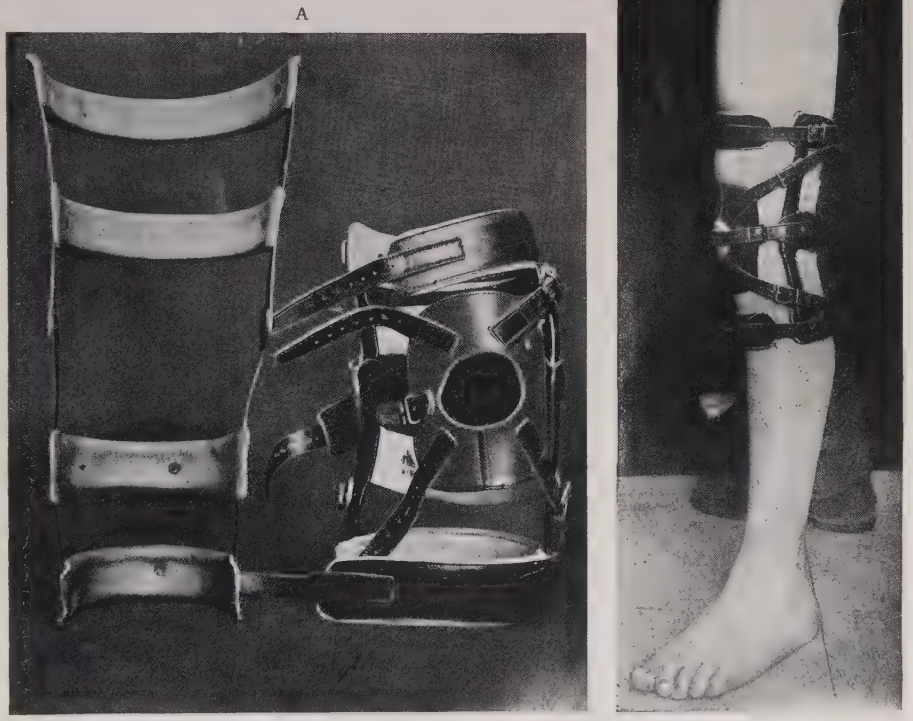


FIG. 794.—(A. B.) The Jones knee-cage, required during the convalescent period in certain cases of tear of the lateral or crucial ligaments. (A) View of the splint itself. The one on the left is devoid of straps, in order to show its construction. (B) The splint applied.

at operation it is a common experience in old-standing cases to find that only a small part of the ligament remains.

Diagnosis.—In the recent case, swelling and ecchymosis are present, but the outstanding diagnostic feature is hypermobility of the joint in the antero-posterior plane. When the anterior crucial ligament is ruptured this is demonstrated by the fact that it is possible to displace the tibia forward on the femur, the knee being extended. When the posterior ligament is ruptured it is possible to displace the tibia backward on

the femur, the knee being flexed. Internal rotation of the tibia on the femur, the knee being extended, is abnormally free in both cases but is more marked when the anterior crucial is affected. The examination should include investigation of the condition of the internal lateral ligament and internal semilunar cartilage, and finally a roentgenogram should be made to exclude the possibility of a fracture of the spine of the tibia.

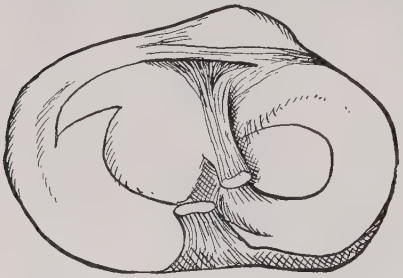


FIG. 795.—Diagrammatic representation of tear of the anterior portion of the internal semilunar cartilage.

Treatment.—Rupture or stretching of the crucial ligaments should be treated by immobilization of the joint, more or less prolonged. In the recent case, the prognosis as to function is good, and in the chronic case proper treatment should result in a very considerable improvement of function. In the recent case, if there is much swelling the joint may be aspirated. Immobilization is obtained by fixation in a plaster of Paris cast extending from ankle to groin, with the knee in a position of 30° flexion (Fig. 798). Such fixation should continue for six months, weight-bearing in the cast being allowed after the lapse of two months. Following removal of the cast, a knee-cage (Fig. 794), the joints of which are blocked in order to limit the last 20° of extension, should be worn for two to four months. The cage may be removed daily for massage and movement. The stiffness from such prolonged fixation is found to be only temporary. In the less severe cases of stretching, the cast should be bivalved and massage begun at the end of one month and active and passive motion at the end of two months. Operation is rarely required in a case properly treated from the beginning, and experience has shown that approximation and suture of the torn ligaments is rarely possible. Various operative procedures aiming at the reconstruction of the damaged ligaments by the transplantation of fasciæ or tendons have been devised (Hey Groves[6] and Alwyn Smith[7]), but their value is still *sub judice*.

4. FRACTURE OF THE TIBIAL SPINE

Types of Fractures and Causation.—Fracture of the tibial spine is not a common injury, although with more frequent roentgenological examination it is found to be of less rare occurrence than was formerly suspected. It may occur as an avulsion injury from the pull of the anterior crucial ligament, which is attached in close relation to the internal tubercle of the spine. The mechanism in such a case is the same as that which causes rupture of the ligament itself, usually hyperextension of the knee. In

[6] E. W. Hey Groves, *Brit. Journ. of Surgery*, April, 1920.
[7] S. Alwyn Smith, *Brit. Journ. of Surgery*, October, 1918.

other cases the injury is produced as a secondary result of rupture of the internal lateral ligament, the external condyle of the femur displacing mesially and fracturing the external tubercle of the tibial spine by direct violence (Jones[8]). Still other cases result from direct crushing injuries associated with fracture of the tuberosities of the tibia. In these cases, fracture of the internal tubercle is associated with fracture of the external tuberosity of the tibia, while fracture of the external tubercle is associated with fracture of the internal tuberosity.

Diagnosis.—The signs are those of considerable injury to the knee, with pain, disability, and swelling. The joint may be abnormally movable in the antero-posterior plane from associated rupture of the anterior crucial ligament. The only sign on which a diagnosis may be based is locking of the joint on extension, and this may be absent. The character of the jamming of the bones suggests an osseous block and it is distinct from the elastic type of jamming that is associated with a displaced or torn semilunar cartilage. Roentgenograms should always be made and in case of fracture the injury is clearly demonstrated (Fig. 799).

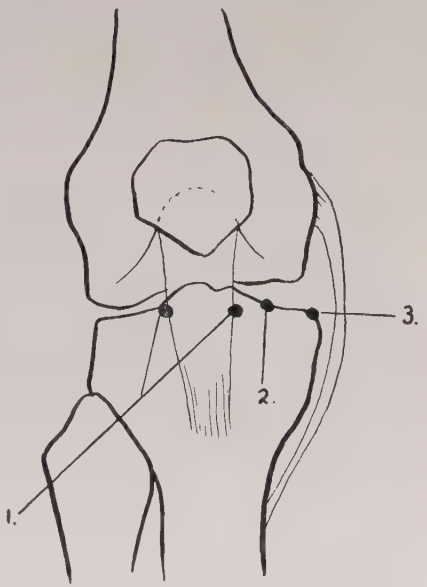


FIG. 796.—Differential diagnosis of traumatic lesions of the knee. (After Jones.) (1) Points of tenderness in case of pinching of an hypertrophied infrapatellar fat pad. (2) Point of maximum tenderness in dislocation of the internal semilunar cartilage. (3) Point of maximum tenderness in case of injury to the internal lateral ligament.

Treatment.—Treatment aims at getting rid of the bony blocking, when present, and in trying to obtain union of the fragments by immobilization in plaster for a period of 6-8 weeks. Manipulation may be attempted under anæsthesia, the knee being flexed and the leg rotated until full extension of the knee is possible. If this fails to remove the obstruction, arthrotomy by an anterior, median incision, splitting the patella, is indicated, with complete removal of the detached fragment.

5. INJURY OF THE INFRAPATELLAR PAD OF FAT

Anatomical Considerations.—The infrapatellar pad of fat is an intra-articular, but extra-synovial, structure which occupies the space between the femur and the tibia behind, and the infrapatellar tendon in front (see Fig. 736). It functions as a cushion. It is attached above to the lower part of the patella and adjacent capsule. Its posterior border is free and

[8] R. Jones and S. Alwyn Smith, *British Journ. of Surg.*, Vol. 1, No. 1, 1913.

lies enclosed in a process of synovial membrane, the ligamentum mucosum, which passes backward and slightly outward to receive attachment to the front of the intercondyloid notch of the femur. Prolongations of this fold extend forward and laterally to the capsule. The free edges of these prolongations are called the alar ligaments. When the joint is extended, the pull upon the capsule is transmitted to the ligamentum muco-

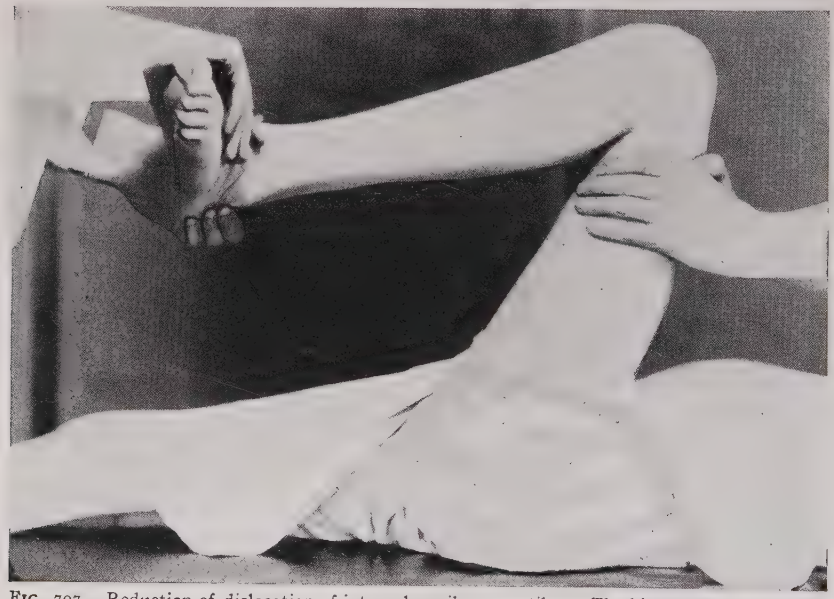


FIG. 797.—Reduction of dislocation of internal semilunar cartilage. The hip and the knee are flexed acutely and the lower leg externally rotated and abducted. The reduction is accomplished by a quick extension of the knee.

sum and alar ligaments, thus preventing injury of the latter between the articulating surfaces.

Causation and Pathology.—The free posterior border of the fat pad, as also the synovial membrane covering it, are often made irregular by uneven deposition of fat, and in this way the synovial fringes at the edge of the ligamentum mucosum on either side are liable to overgrowth. This appearance is not unusual in stout subjects. If, in addition, there is a rheumatic tendency, the early stage of hypertrophy of these fringes which goes to form a villous arthritis may be encountered. Sometimes these overgrown fringes contain so much fat that they form actual lipomata. Because of the tendency of these patients to stand with the knees slightly flexed, the ligaments become lax and the quadriceps extensor muscle weaker than normal. The weakness of the quadriceps impairs its supporting function in bracing the patella upon the femur and so assisting to pull the infrapatellar pad of fat and its overgrown fringes out of harm's way. Under such conditions, it is readily possible for the villi to be pinched between the bones during some unguarded movement of the joint. With

the nipping of such an hypertrophied fringe there results a slight synovitis which occasions further hypertrophy of the fringes and greater weakening of the quadriceps, so that a vicious circle is easily established. When injured by external violence, the primary lesion is a bruising and congestion of the pad, and sometimes a small extravasation of blood which organ-

FIG. 798.—Plaster casing extending from ankle to groin, holding the knee in slight flexion, as would be indicated in case of an injury of the crucial ligament.

izes and replaces the fat. A tear in the synovial covering of the pad may result in herniation of the fat into the joint and, with repeated trauma, the appearance of an exuberant growth of fat in the upper part of the anterior compartment of the knee-joint.

Diagnosis.—The patients are generally middle-aged and stout. They complain of transitory attacks of pain and swelling in the knee and often a dull ache behind the patella (Jones [9]). Examination may reveal irregular thickening about the infrapatellar tendon, tender on deep pressure. The amount of induration varies according to the extent of the fibrous changes. The adjacent capsule is but little thickened. Joint motion is apt to be slightly limited in complete extension, and movement is accompanied by fine crepitation. Atrophy of the quadriceps is demonstrable. Differentiation from lesions of the internal semilunar cartilages is based upon the absence of locking and the fact that the pain and tenderness, instead of being referred to the inner side of the joint, are localized behind the patellar ligament (Fig. 796). In old-standing cases, the roentgenogram shows an increase in the density of the shadow cast by the fat pad.

[9] R. Jones, *Clinical Journal*, May 9, 1906. *British Medical Journal*, August 5, 1916.

Treatment.—Treatment is aimed to protect the hypertrophied tissue from further internal trauma until it can shrink to normal size and to build up the tone and strength of the quadriceps muscle. Temporarily, at first, it may be necessary to have the patient recumbent. An adhesive strapping to the front of the knee will tend to pull the fringes from between the joint surfaces. This may be followed by the use of an elastic knee cap. The application of heat is also helpful. Massage and active exercises to strengthen the quadriceps are fundamental. Cases which resist such treatment call for operative removal of the fatty mass or hypertrophied synovial fringes. In the case of the former the incision is made internal to the lower part of the patella. No functional disability follows the removal of the tissue (Jones). Skillern practises a synovial capsulectomy in certain cases, removing a considerable portion of the synovial membrane with its hypertrophied fringes.

6. LOOSE BODIES

Loose Bodies Resulting from Disease.—Clinically and pathologically, interest in loose bodies centres round those present in a knee which is otherwise healthy. In a knee which is the seat of tuberculosis, hypertrophic arthritis or Charcot's disease, fibrinous loose bodies, the so-called "rice grains" or "melon-seed" bodies, rarely if ever obtrude themselves upon the surgeon's notice apart from the disease which gives them origin. This also applies to the bodies composed of organized connective tissue which are encountered in the same conditions. In hypertrophic arthritis, they are usually nothing but overgrown synovial fringes and consist entirely of fat (arborescent lipoma). Synovial chondromata and osteo-cartilaginous bodies are also found in the same conditions. The latter are hypertrophic nodules which have broken away from the periphery of the articular surfaces. Such hypertrophied fringes, whether fatty, fibrous, or cartilaginous, tend to become pedunculated, and finally, in some cases, free. The size and number of these bodies may vary greatly. A cartilaginous body which is free in the joint may increase in size. In tabes, bodies composed of bone, originating from the capsule, ligaments, or articular margins, may be present and cause a characteristic grating when the joint is moved. As stated above, it is rare for any of these types of loose bodies to become blocked between the articular surfaces, and treatment is concerned mainly with the disease that gives them origin.

Other Loose Bodies.—Loose bodies in a joint otherwise healthy, giving rise to the classical symptoms of impaction between the articular surfaces and calling for operative relief, constitute a different class. They occur (1) as circular or oval osteo-cartilaginous bodies representing portions

of the articular cartilage which have become detached; or (2) as single or multiple chondromas or osteomas originating usually from the synovial membrane.

Osteochondritis Dissecans.—The characteristics of the first group are remarkably constant. The bodies are usually solitary, circular or oval, about the size of an almond, and concavo-convex in shape. The convex aspect is smooth and covered by articular cartilage; the concave surface is bony, uneven, and nodulated. Their most constant location is a defect in one of the articular surfaces, usually the medial condyle of the femur or the vicinity of the femoral attachments of the crucial ligaments. The spongy bone of the loose body is usually dead, but the cartilage cells remain nourished by the synovial fluid and do not die. If the body is incompletely detached from its pit or if it establishes a new attachment it may show the formation of new bone (Surls and Osgood).

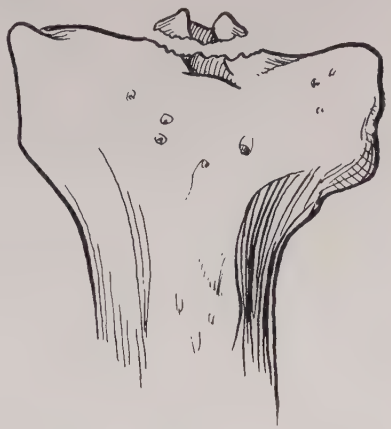


FIG. 799.—Fracture of the tibial spine.

Origin.—The origin of these bodies is a much-debated question in surgical pathology. Obviously they are portions of the articular surfaces of one of the bones, and how and why such detachment takes place is not settled. Timbrell Fisher [10] explains it on the basis of trauma, while König [11] states that they are separated by a morbid process, the so-called "osteochondritis dissecans." Colvin [12] exploits a theory of infectious osteitis, and finally Axhausen [13] claims that the nutrition of the part is shut off by an embolus and that trauma completes the process.

Diagnosis.—The average age is 38 years. A history of trauma may or may not be forthcoming, but an interval elapses between the date of injury and the onset of symptoms. The patients complain of transitory locking of the joint and of pain and grating upon movement. The pain is often referred to different parts of the joint and not to one particular situation, as in injury of the semilunar cartilages. When the body becomes impacted, there is sudden intense sickening pain, loss of power in the limb, and fixation of the joint, followed by swelling. The patient is usually sufficiently experienced from previous attacks to have devised some special manœuvre for dislodging the body and freeing the joint. Upon examination the joint is usually found to contain fluid and the ligaments

[10] A. G. Timbrell Fisher, *Brit. Journ. of Surg.*, April, 1921, p. 493.
[11] König, *Archiv f. klin. Chir.*, Vol. 59, No. 1.
[12] A. R. Colvin, *Minnesota Medicine*, February, 1920.
[13] G. Axhausen, *Archiv f. klin. Chir.*, May 22, 1914, CIV, No. 3.

are lax. The surgeon may be able to palpate the loose body and it may be felt to slip about inside the joint. Very often the patient diagnoses the condition himself. A roentgenogram gives positive evidence and is necessary to show whether the body is single or multiple.

Synovial Chondromas and Osteomas.—These may be either single or multiple, pedunculated or free. They may occur in great numbers, one case

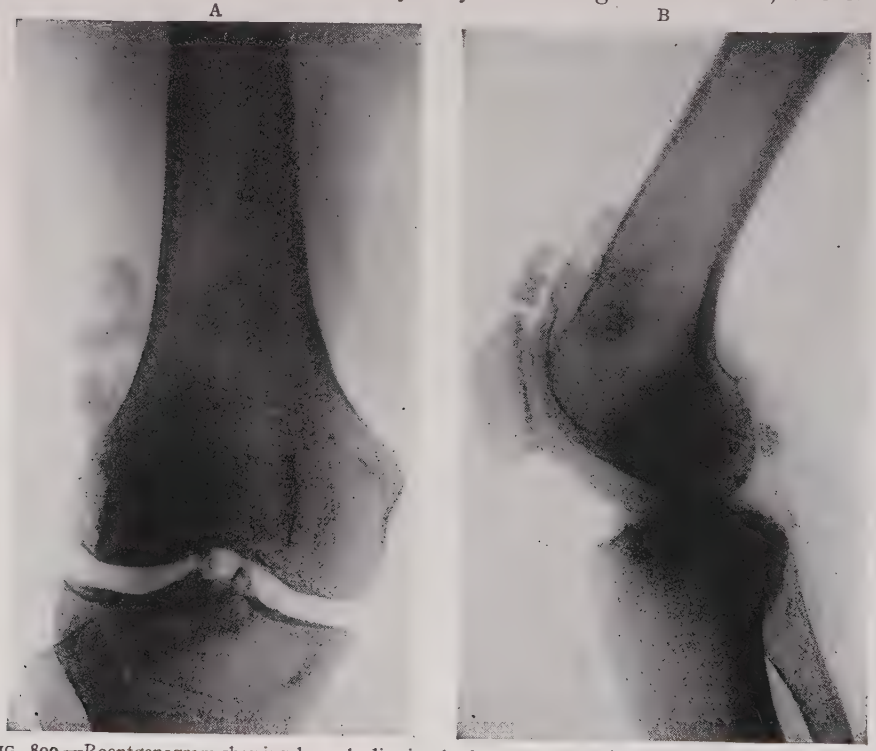


FIG. 800.—Roentgenogram showing loose bodies in the knee-joint. (A) Anterior view. (B) Lateral view.

yielding over 1000 at operation (Osgood and Surls). The single bodies are larger than the multiple ones and tend to occupy recesses in the synovial chamber. Hence they are less likely to cause locking. They are thought to arise as villous prolongations of the synovia in which cartilage or bone is deposited and which later become detached.

The symptoms are similar to those described above and are due to the mechanical action of the bodies in hindering movement. The function of the joint becomes increasingly restricted and painful. On examination the presence of effusion may be recognized and, occasionally, some of the loose bodies may be palpated. The diagnosis should be confirmed by roentgen examination (Fig. 800).

Treatment.—The treatment consists in opening the joint and removing the loose bodies. This procedure is indicated even when the body is giving

rise to no symptoms. Trouble is sure to result, sooner or later, and the mechanical irritation leads to arthritic changes in the joint. If the body is single the attempt should be made to bring it into a palpable position before operation. If it lies in the anterior compartment it may be pushed into the suprapatellar pouch by fully extending the knee and kneading it upward. If this succeeds only a small incision is required and local anæsthesia is satisfactory.

The best method of exploring the anterior chamber of the knee is by the split patellar incision. The popliteal incision [14] is usually the best for exploring the posterior compartment. This is a longitudinal incision just internal to the midline; the vessels and nerves are pulled to the outer side. Postero-lateral incisions are suggested by Henderson.[15] They are made with the knee fully extended, the external one just outside the biceps tendon and the internal one just internal to the tendon of the semimembranosus. Post-operative fixation is not required save in the split-patellar incision, when fixation for 1-2 weeks in a posterior splint is advisable.

[14] E. G. Brackett and R. B. Osgood, *Boston Med. and Surg. Journ.*, Dec. 28, 1911, p. 975.

[15] M. S. Henderson, *Surg., Gyn. and Obstetrics*, December, 1921, p. 698.

CHAPTER XVII

FRACTURES OF THE SHAFT OF THE TIBIA AND FIBULA

I. FRACTURE OF THE SHAFT OF THE FIBULA (UNASSOCIATED WITH INJURY OF THE ANKLE-JOINT)

II. FRACTURE OF THE SHAFT OF THE TIBIA ALONE

III. FRACTURE OF BOTH BONES OF THE LEG

ANATOMICAL CONSIDERATIONS

The Shaft of the Tibia.—The shaft of the tibia is formed above by an abrupt narrowing of the tuberosities and terminates below in an expansion for the ankle-joint. The shaft is triangular on cross section in its upper two-thirds, but grows progressively smaller and becomes circular in its lower third. Because of this constriction and also on account of the circular form, which is less strong mechanically than a triangular shape, the lower third constitutes the weak point and is by far the most common site for fractures of the shaft.

Of the three borders of the tibia, the anterior is most prominent and is composed of dense cortical bone and known as the crest. It may normally be palpated on the anterior surface of the leg beginning just below the tibial tubercle and descending in a fairly straight line to the lower third, where it is usually lost. The postero-external border is sharp for the attachment of the interosseous membrane, but is concealed from palpation. The postero-internal border is rounded and less prominent, but may be traced in the upper two-thirds of the normal leg.

The mesial surface of the tibia is subcutaneous throughout, being covered only by fascia, but the external and posterior surfaces are hidden by muscular covering. On account of the small amount of tissue covering its anterior surface, fractures of the tibia are often compound. The nutrient artery enters the bone through a foramen on the posterior surface close to the external border at about the junction of the upper and middle thirds, and is directed downward.

The Fibula.—The fibula is long and slender and surmounted by a knob-like head with a small pointed styloid process and can be readily palpated under the skin just below the knee. The upper surface is occupied by the articular facet, which is roughly quadrilateral in shape and looks upward, inward, and a little forward. The corresponding articular facet of the tibia is small and lies under the external tuberosity at the junction of the posterior and external surfaces, not far from the articular surface. The neck of the fibula lies at the junction of the shaft with the enlarged head. Below this the shaft increases in thickness and is marked by four borders with intervening surfaces. The antero-lateral border receives the insertion of the interosseous membrane and forms a prominent ridge, which, however, is concealed from palpation.

Ossification of the Fibula.—The development of the epiphyses of the fibula is an exception to the rule that the epiphysis toward which the nutrient vessel is directed is the last to appear and the first to unite. The lower epiphysis appears in the second year and fuses with the shaft at eleven to nineteen, while the upper epiphysis appears about the fifth year and unites at twenty. The nutrient vessel enters at about the middle of the shaft and is directed downward, but, nevertheless, growth occurs chiefly at the lower epiphysis. On account of the protected position of the upper epiphysis and its close relation to, and participation in, the strong ligamentous support of the joint, disjunction is a very rare accident. Displacement of the lower epiphysis will be considered in connection with the ankle-joint.

The Superior Tibio-fibular Articulation.—The fibula and tibia are joined together in much the same manner as the radius and ulna. The fibular head enters into a true

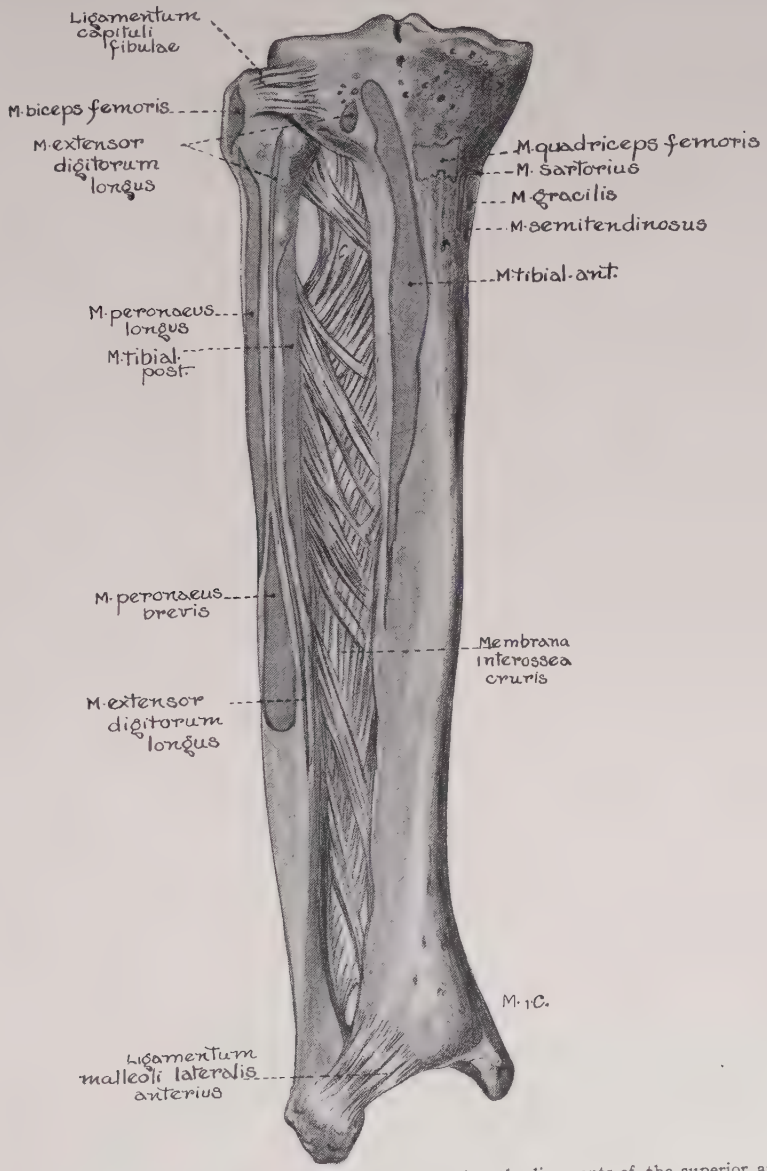


FIG. 801.—Anterior surfaces of the tibia and fibula, showing the ligaments of the superior and inferior tibio-fibular articulation, the interosseous membrane, and the points of muscle attachment.

articulation with the facet of the tibia and is enclosed by a capsular ligament, which occasionally communicates with the knee-joint by a small opening. The capsule is strengthened by thickenings which are known as the anterior and posterior superior

tibio-fibular ligaments. In addition, the joint is reinforced by the external lateral ligament of the knee and the tendon of the biceps, both of which are inserted into the head

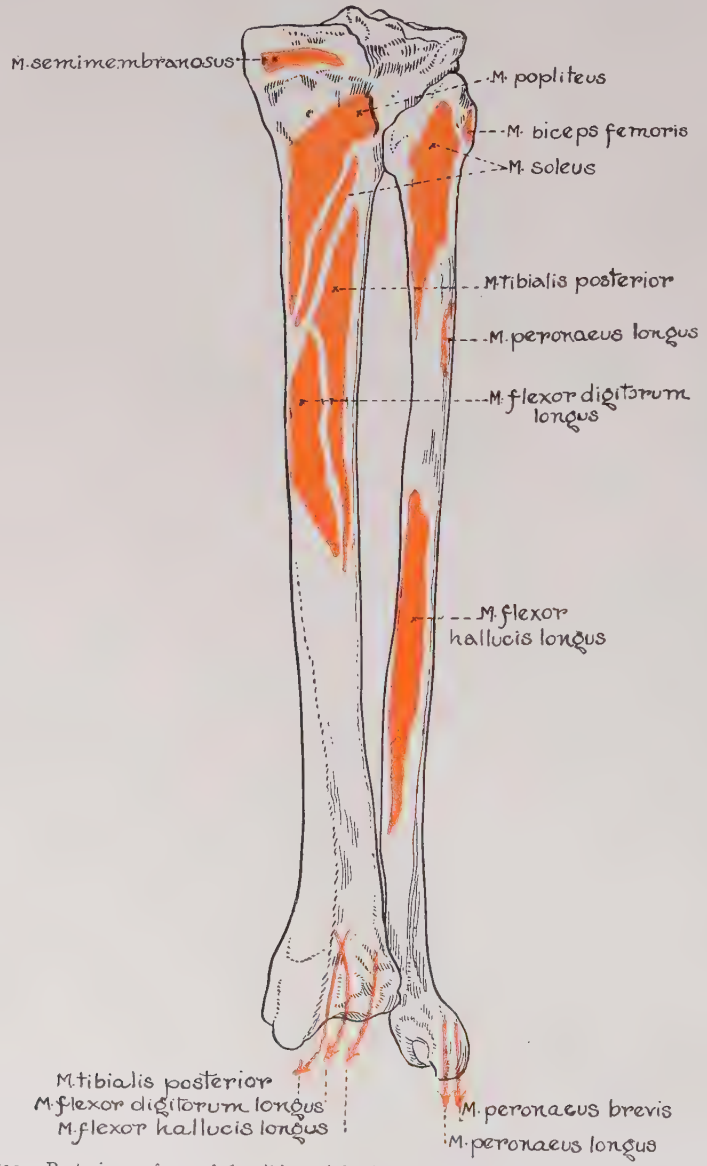


FIG. 802.—Posterior surfaces of the tibia and fibula, showing the points of muscle attachment.

of the fibula. The joint is very strong and so situated as not often to be exposed to direct violence. Dislocation, therefore, is very rare.

Interosseous Membrane.—The interosseous membrane is a strong, fibrous sheet entirely closing the space between the tibia and fibula except for a small opening above. Its fibres run chiefly downward and outward. Because of this connection, indirect violence acting on the tibia may be transmitted to the fibula. In case of fracture of one

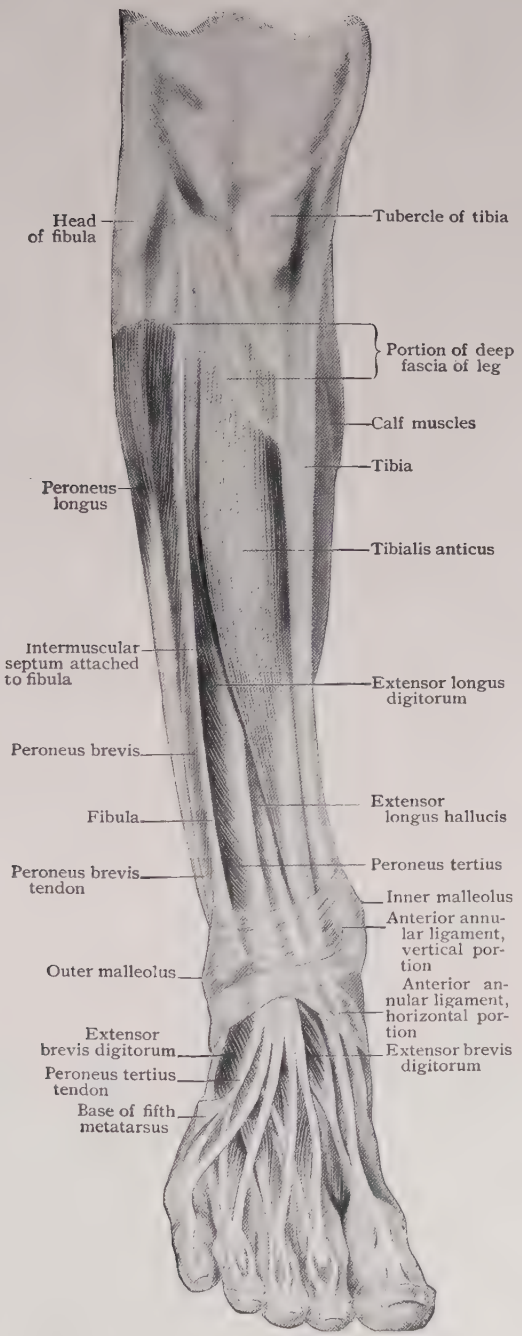


FIG. 803.—Muscles of the anterior surface of the leg. (Piersol: Human Anatomy.)

bone alone it has a strong effect in limiting displacement, and in fracture of both bones prevents separation of the tibia from the fibula, unless extensively torn.

Function of the Tibia and Fibula.—In considering the leg as a whole it will be seen that the tibia, through its articulation above with the femur and below with the astragalus, transmits practically the entire body weight. The fibula has only a slight

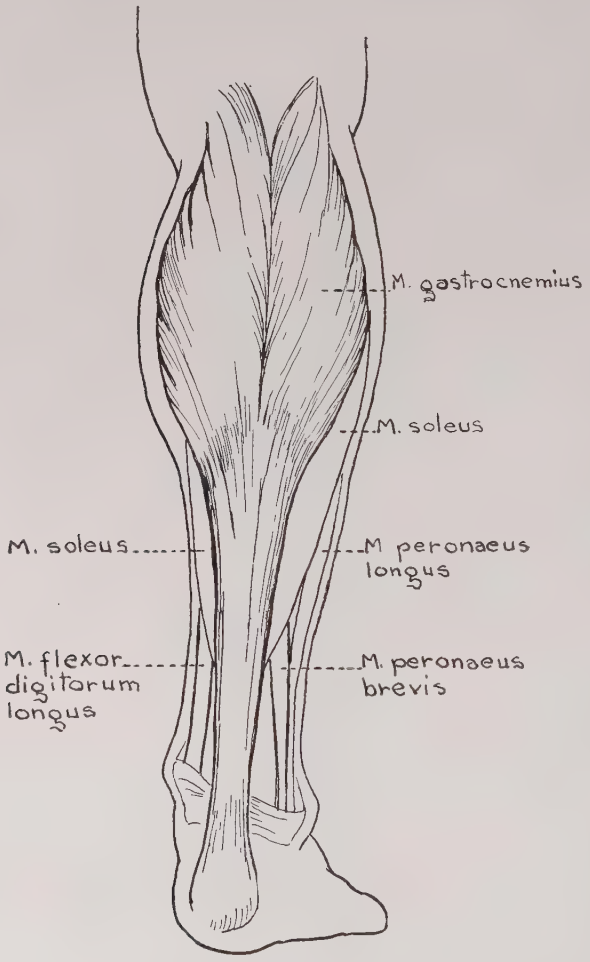


FIG. 804.—The posterior surface of the leg, showing the superficial layer of muscles.

amount of movement at the superior tibio-fibular joint, chiefly a slight degree of rotation or play in the antero-posterior direction. This motion is necessary to permit change in the relation of the articular surfaces of the ankle-joint in varying positions of flexion and extension of the foot, but has no other function. The fibula does not participate in weight-bearing, but may, however, be of service in reinforcing the tibia in case of strain. The upper third or half of the bone is not infrequently excised for bone-grafting purposes, and its removal causes no apparent interference with function. The lower third of the bone, however, is important because it plays a part in the formation of the ankle-joint.

Muscles of the Leg.—The muscles of the leg are arranged in four groups, each contained in separate fascial compartments. The extensor group, consisting of the tibialis anticus, extensor longus digitorum, and extensor longus hallucis muscles, lies

in the front of the leg, taking its origin from the external surface of the tibia, the interosseous membrane, and the mesial surface of the fibula (Fig. 803). The abductor group, consisting of the peroneus longus and brevis, lies external to the extensor group and takes its origin from the lateral surface of the fibula. The flexor group, composed of the tibialis posticus, flexor longus digitorum, and flexor longus hallucis, arises from the back of the tibia and fibula and the interosseous membrane. Overlying them posteriorly and separated from them by an intermuscular septum is the great muscular mass of the triceps suræ, consisting of the gastrocnemius, soleus, and plantaris. The two former muscles insert by means of the tendo Achillis into the posterior portion of the

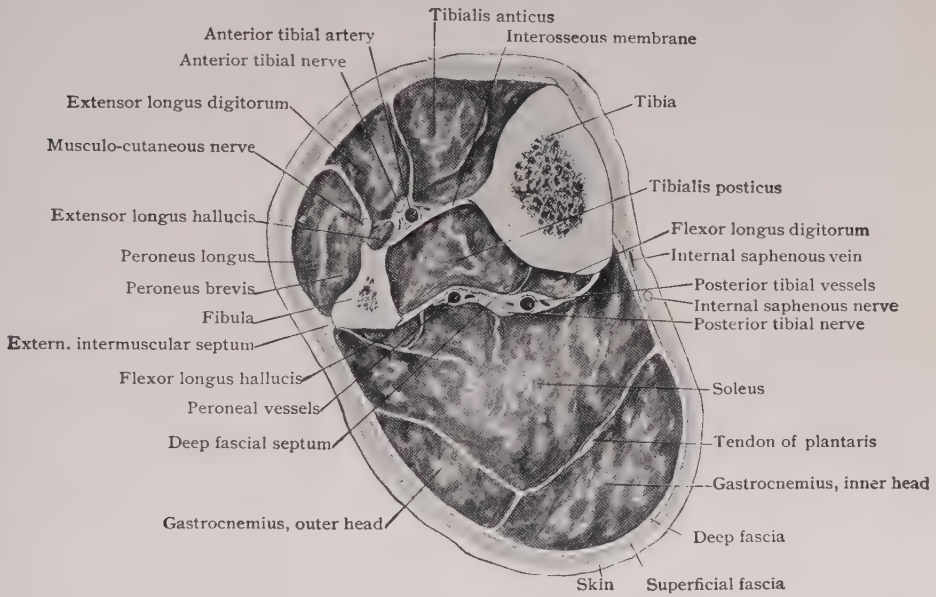


FIG. 805.—Section through right leg at junction of upper and middle thirds, showing relations of the vessels and nerves. (Piersol: Human Anatomy.)

tuberosity of the os calcis. These are the great walking and running muscles, their contraction being necessary to fix the foot, lift the heel, and propel the body forward.

Arteries.—The blood supply is obtained from the anterior and posterior tibial and peroneal arteries. The course of the posterior tibial may be represented by a line running from the middle of the popliteal space to a point midway between the internal malleolus and the internal tuberosity of the os calcis. It lies deep in the calf upon the flexor longus digitorum and in close relation to the posterior tibial nerve which lies to its outer side. Both of these structures are liable to injury in fracture, but this is of infrequent occurrence because of the muscular layer interposed between them and the bone. The peroneal artery, a branch of the posterior tibial, lies in close relation to the internal border of the fibula and is doubtless often injured in fracture, but being of small size it is relatively unimportant. The anterior tibial artery passes to the front of the leg through the opening in the interosseous membrane and is directed downward, lying between the extensor longus digitorum and tibialis anticus muscles. It may be injured in case of a fracture with considerable displacement.

External Popliteal Nerve.—The superficial position of the external popliteal nerve, as it emerges from behind the biceps tendon on the lateral surface of the leg and winds around the head of the fibula to pass to the anterior surface, is important because the nerve is exposed to injury either from trauma or the pressure of dressings or splints. Below the level of the head of the fibula the nerve divides into the anterior tibial and musculo-cutaneous divisions. The former joins the anterior tibial artery, which it accompanies down the leg to the foot, where it breaks up into cutaneous branches.

The latter descends in the front of the peroneal muscle compartment to the lower third of the leg, where it becomes superficial and supplies the skin.

The flexor muscles of the toes and the triceps suræ are supplied by the posterior tibial nerve; the extensor muscles of the toes and the tibialis anticus by the anterior tibial nerve; while the peroneal muscles are innervated by the musculo-cutaneous nerve.

I. FRACTURE OF THE SHAFT OF THE FIBULA

(Unassociated with injury of the ankle-joint)

Types of Fractures and Causation.—Fracture of the fibula unassociated with fracture of the shaft of the tibia rarely occurs except as a result of strain of the ankle-joint with leverage force acting on the lower end of the bone. Such injuries will be considered separately in the section on the ankle-joint.

The remaining fractures of the fibula, after excluding the above types, are of but little practical importance. The head of the bone, which is superficially situated, may be splintered by a blow. A few cases are on record of disjunction of the upper epiphysis, produced apparently by muscular force acting through the biceps tendon. Dislocation at the superior tibio-fibular joint is practically unknown.

Fracture of the shaft by direct violence does occur, but infrequently. Any level may be affected. It is rare in any case to have displacement of any importance because of the strong muscular attachments and practically never is the injury compound (Fig. 806).

Diagnosis.—The fracture is recognized on examination by localized tenderness on pressure over the seat of fracture and pain referred to the same region when the fibula is pressed strongly inward against the tibia either above or below the point of injury. Crepitus is rarely demonstrable.

Treatment.—Treatment is by immobilization in a plaster of Paris boot extending from the toes to just below the knee. When displacement is present, it may usually be corrected by pulling down on the foot and strongly inverting it. This pulls inward on the external malleolus, and with the inferior tibio-fibular ligaments serving as a fulcrum, tends to correct inward displacement of the lower fragment. Anæsthesia is unnecessary. Displacement which cannot be corrected by this method is usually of little functional significance, provided there is sufficient approximation to obtain union.

Immobilization should be continued for three to four weeks, but weight-bearing on the uninjured leg, with the aid of crutches, may be permitted from the first. Many of these fractures might well be treated by the method of massage and mobilization without other fixation than that provided by a bandage. Certainly over-treatment is a danger to be avoided, and weight-bearing may be permitted at the end of three to four weeks.

II. FRACTURE OF THE SHAFT OF THE TIBIA ALONE

Occurrence.—The tibia may be fractured without associated injury of the fibula. This accident may occur at any age, but is particularly com-

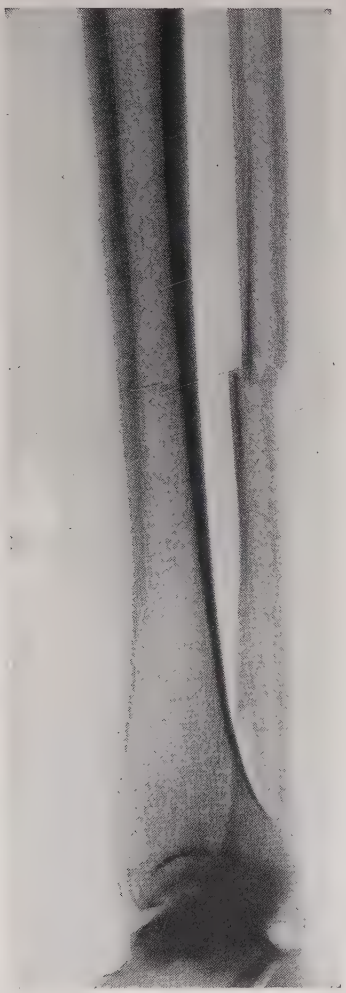


FIG. 806.—Roentgenogram of fracture of the fibula by direct violence. (Fracture Service, M. G. H.)

mon in children and young adults. It is usually the result of direct violence, such as a blow on the leg or crushing injury. It may also be produced by a torsion strain acting through the foot. Fracture of the tibia alone by indirect violence, however, is uncommon, because a force sufficient to cause this bone to give way usually continues to act long enough to break the much weaker fibula. The fracture may occur at any level, but the favorite site is at the junction of the lower and middle thirds, which

represents the weakest part of the bone. The fracture line is usually oblique or spiral and runs upward and backward.

Displacement.—There is rarely great displacement of the bones because of the splinting action of the intact fibula. The lower end of the upper

807 808

FIGS. 807 and 808.—Fracture of the tibia, showing limited amount of displacement due to the intact fibula. (807) Anterior view. (808) Lateral view. (Fracture Service, M. G. H.)

fragment projects anteriorly and mesially in relation to the lower fragment, due chiefly to the action of the quadriceps muscle. The contraction of the gastrocnemius-soleus muscle group also tends to produce anterior angulation of the fragments. On account of the subcutaneous situation of the tibia and the direct type of trauma, the injury is not infrequently compound (Fig. 809).

Diagnosis.—There is always much disability and pain. The deformity is inconspicuous, but swelling is marked. The diagnosis can usually be made from palpation of the shin. If the crest of the tibia is traced downward, an abrupt jog is encountered at the point of fracture, and the lower

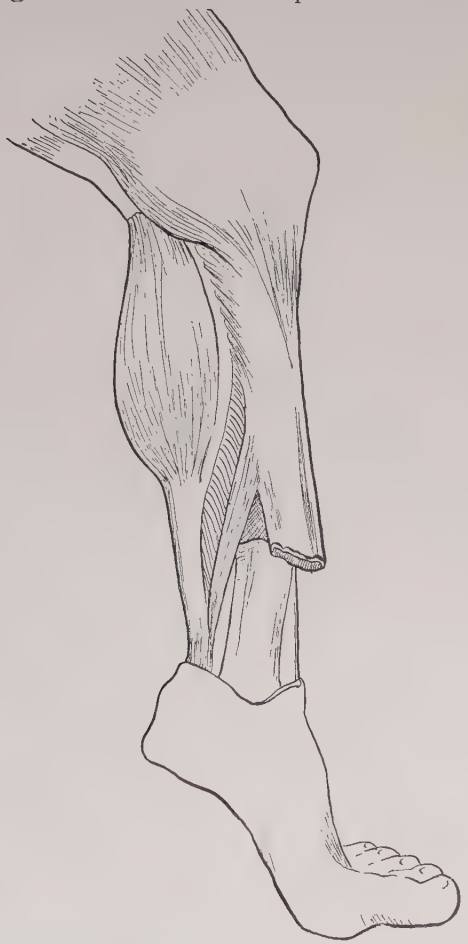


FIG. 809.—Fracture of both bones of the leg, showing the most common type of displacement, the upper fragment of the tibia being displaced forward and inward in relation to the lower fragment.

end of the upper fragment may be felt projecting under the skin. Gentle lateral bending reveals abnormal mobility and crepitus and causes pain referred to the point of injury. Tenderness on pressure, sharply localized over the fracture-line, is marked.

It is usually easy to make the diagnosis of fracture of the tibia, but it is more difficult to recognize that the fibula has escaped injury. Determination of the latter fact is chiefly dependent upon the absence of gross deformity and the limited mobility of the leg at the seat of fracture.

When both bones of the leg are fractured, angular deformity can be produced by moving the lower portion of the leg in any direction, but with the tibia alone injured this is impossible.

Causation.—The treatment of fracture of the tibia is the same as that of fracture of both bones of the leg, the only difference being that the former is, as a rule, much easier to reduce and maintain in the corrected position because of the splinting action of the intact fibula. The treatment of the two conditions, therefore, will be considered together (p. 650).

III. FRACTURE OF BOTH BONES OF THE LEG

Causation.—Fracture of both bones of the leg is a very common and at the same time severe injury. It may occur at any age, but is most frequent in children and young adults. It may be produced by either direct or indirect violence, and the types of fracture encountered with each are more or less characteristic. The direct type of trauma usually consists of a severe blow, such as is produced by a falling object or a collision with an automobile, or the injury may be of a crushing character, such as results from being run over. Indirect violence may be of a nature to produce a lateral bending effect upon the leg, such as falling to the side when the foot and ankle are fixed, or of a rotational nature, such as a twisting fall producing a torsion strain upon the leg. It is probable that in most cases the strain from indirect violence partakes of the nature of a bend and twist combined.

Fracture by Direct Violence.—When the injury is due to direct violence the fracture may occur at any level and is frequently situated in the upper half of the leg. Both bones are fractured at approximately the same level and the fracture line tends to be transverse and comminuted. It is frequently compound, and being the result of direct violence, there is much laceration and contusion of tissue and often a large wound (Fig. 810).

Fracture by Indirect Violence.—When the cause is indirect violence the tibia usually fractures at its point of greatest weakness, that is, at the junction of the lower and middle thirds, while the fibula breaks at a considerably higher level. The fracture-line in the tibia is usually oblique or spiral, with its direction upward and backward. When comminuted, there are usually only one or two large pieces in addition to the main fragments. When compound, the wound is the result of the protrusion of a fragment through the skin and may vary in size from a small puncture wound to a large opening. The tissues are less extensively traumatized than with the direct type of fracture.

Displacement.—There is no constant type of displacement, but in general there is a tendency for the upper fragment of the tibia to lie anterior and mesial to the lower one and for the distal portion of the leg to be

externally rotated with reference to the upper segment. The displacement may be complete or incomplete. The interosseous space may be narrowed, but never widened. When the fragments are completely displaced, shortening and over-riding gradually develop and may amount to as much as one to two inches. Shortening of considerable extent is rarely present in the first four to five hours after injury (Figs. 811 to 814).

Diagnosis.—The diagnosis seldom presents any difficulty and can be made from the angular deformity alone. Abnormal mobility is always

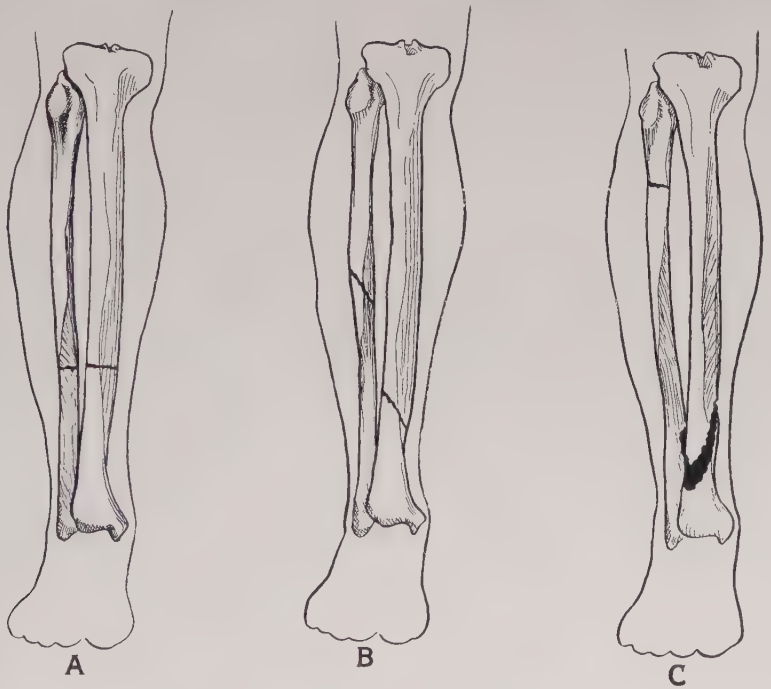


FIG. 810.—Fracture of both bones of the leg. (A) Fracture by direct violence. (B) Fracture by indirect violence. (C) Fracture by rotation.

marked, so that there is complete flail-like movement at the point of fracture. Swelling quickly develops and masks the position of the individual fragments. Extreme gentleness should always attend the examination for fear of causing additional injury to the soft parts or of making the injury compound. It is unnecessary to elicit crepitus.

Injury of the Vessels and Nerves.—The examination should always include tests to show the presence or absence of injury to the vessels and nerves. Rupture or compression of the posterior tibial artery is indicated by brawny swelling of the calf of the leg and pallor and coldness of the foot. Injury of the anterior tibial artery is less important, but usually causes marked swelling of the front of the leg and disappearance of pul-

sation in the dorsalis pedis artery. Nerve function may be satisfactorily tested by simple movements of the toes and ankle. Inability to extend the toes indicates injury of the anterior tibial nerve, absence of toe flexion

811

812

FIGS. 811 and 812.— Museum specimens illustrating fracture of both bones of the leg. (Warren Anatomical Museum.) In both, the upper fragment lies mesial to the lower fragment, and in 811 a moderate amount of flexion may be noted.

shows injury of the posterior tibial nerve, while, if the musculo-cutaneous nerve is injured, there is failure of the peroneal muscles to contract and inability to evert the foot.

TREATMENT OF FRACTURES OF EITHER THE TIBIA ALONE OR OF BOTH TIBIA AND FIBULA COMBINED

GENERAL CONSIDERATIONS

Relation of Fracture to Function of the Foot.—Fractures of the bones of the leg are only important as they concern the future function of the foot and ankle-joint. If this were not so, then the correction of deformity would be unimportant except for cosmetic reasons, provided that solid union resulted, since an angulated or deformed bone could sustain the

body weight as well as one that was straight. Experience with a single case of malunion following fracture in this region would unforgetably teach the mistake of such a conception. The complaint in such a case

813

814

FIGS. 813 and 814.—Museum specimens illustrating fracture of both bones of the leg. (813) Fracture by indirect violence. Note that the two fractures lie at different levels and that overriding has occurred. (814) Fracture by direct violence. Note that both fractures are at the same level and that cross-union has occurred between the tibia and fibula. (Army Medical Museum.)

is invariably one of pain in the foot and ankle and inability to walk or stand.

Effect of Alteration of the Normal Weight-bearing Lines.—From the mechanical standpoint all parts of the body are related to each other and nowhere is this more strikingly demonstrated than in the leg. The foot is an organ highly specialized for the purpose of bearing the body weight.

Its arched arrangement provides for the distribution of the weight between the heel and forefoot and at the same time gives spring to the gait and protection against strain. The arches are not rigid, but plastic structures and their support is entirely muscular and dependent upon a balanced action of certain muscle groups. This balance is disturbed by any altera-

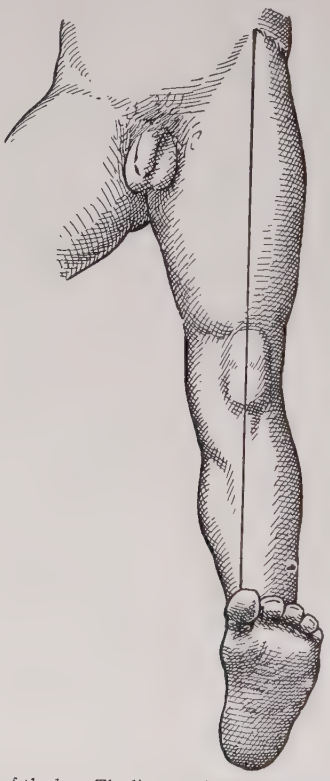


FIG. 815.—The normal alignment of the leg. The line passing from the anterior-superior iliac spine through the centre of the patella should reach the foot at the cleft between the first and second toes.

tion in the normal line of weight-bearing. Normally the body weight is transmitted to the foot in a line falling perpendicularly through the apex of the arch, and the axis of the ankle-joint is horizontal. Any disturbance in these normal relations, such as follows the improper alignment of a fracture of the leg, inevitably results in a strained condition of the foot and ankle when weight-bearing is attempted and in symptoms of weakness and pain.

Fundamental Rules.—With these considerations in mind we may formulate the following rules to be applied in the treatment of fractures of the bones of the leg. They are of considerable importance in securing restoration of function:

1. Complete anatomic reposition should be the goal in all cases, but

slight displacement is not incompatible with good function, provided that the axes of the main fragments of the tibia remain parallel and the tibio-astragaloid joint lies in the normal horizontal plane. In general,

FIG. 816.—Spiral fracture of the tibia from torsion strain. This type of fracture is practically always associated with fracture of the fibula in the upper third, and this feature of the injury is frequently overlooked because the roentgenogram does not include the entire leg. (Fracture Service, M. G. H.)

angular deformity is more to be feared than any other type of displacement.

2. When rigid dressings are necessary, care should be taken during their application to fix the foot and ankle in the position of optimum function, that is, with the ankle at right-angle flexion, the foot inverted, and the arches supported.

3. The fundamental supporting structures of the foot being entirely muscular, it is of the utmost importance to preserve their tone and strength by beginning massage and active movements at as early a date as possible.

4. When weight-bearing is first permitted, the foot being weak, a certain amount of support should be provided by the use of a heel with the

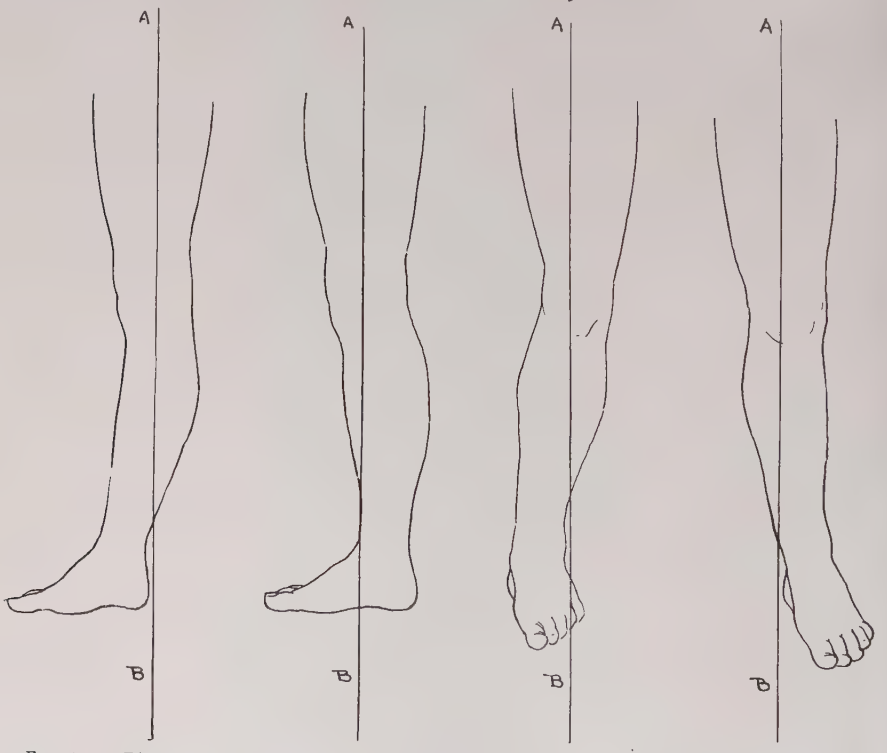


FIG. 817.—Diagrams representing the effect of malunited fractures of the leg in altering the normal line of weight transmission to the foot. The line A-B represents the normal weight-bearing line. The normal relations have been disturbed and secondary strain affecting either the foot, ankle or knee is almost sure to result.

inner border elevated. This slightly inverts the foot and holds it in the position of strength. Unprotected weight-bearing should not be permitted until the muscular function is good.

REDUCTION AND FIXATION METHOD

Availability of the Method.—A large majority of the cases of fracture of the bones of the leg may be successfully treated by the method of manipulative reduction followed by immobilization in plaster. This is possible because the bones are superficially situated and occupy a relatively large proportion of the cross-sectional area of the leg. The muscles enveloping them are for the most part fairly weak, and exert but slight

deforming action in comparison with those of the thigh. If replacement is accomplished, the position can usually be maintained by the application of rigid splints, with little danger of redisplacement.

Importance of the Time Element.—However, the difficulties in the way of obtaining complete replacement of the bones by manipulation greatly

818 819

FIGS. 818 and 819.—Old malunited fracture of the bones of the leg, demonstrating bad alignment with consequently faulty statics. This patient complained of pain in the ankle. (818) Anterior view. (819) Lateral view. (Fracture Service, M. G. H.)

increase with the lapse of time. In the first hour or two reduction is usually quite easy because the muscles are relaxed and swelling is not great. At the end of 10 to 12 hours, considerable exudation has occurred and the muscles have contracted down and hold the bones in their deformed position. Reduction at this time is more difficult and will give a smaller percentage of success. After the lapse of several days it becomes almost impossible to secure replacement in case of severe deformity. The tissues have lost their elasticity from beginning organization of the

exudate and the muscles cannot be completely relaxed. Manipulation at this period exposes the tissues to the risk of fresh laceration, which in turn is likely to have an effect in delaying the return of function.

820

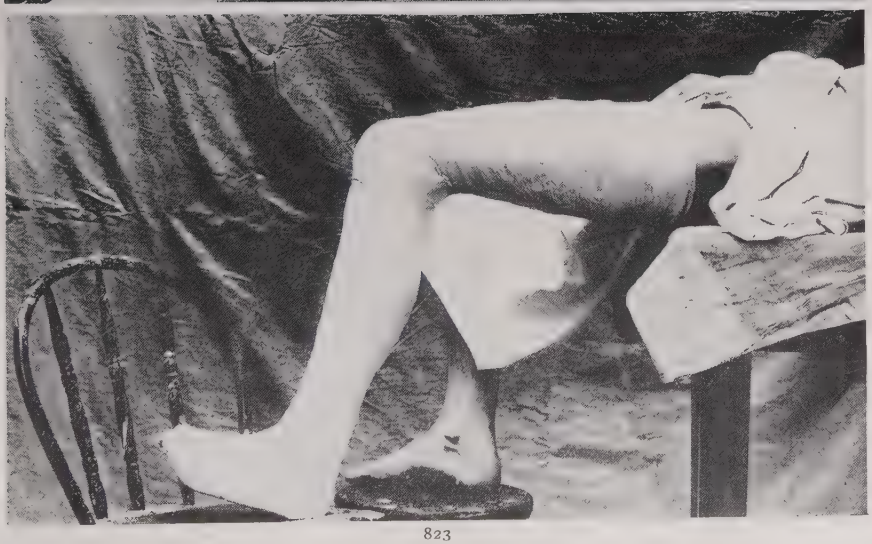
821

FIGS. 820 and 821.—Reduction of a fracture of the leg by the traction method. (820) Traction is obtained by passing a piece of bandage about the ankle in the form of a clove hitch, a soft pad being interposed between it and the skin. The ends of the bandage are knotted about the hips of an assistant, who supports the foot manually and exerts traction by inclining the body backward. Counter-traction is obtained by a supporting band passed around the lower part of the thigh, which holds the knee flexed. (821) In this position, a plaster casing is applied in sections. The first section extends from the ankle to the groin, space being allowed for the removal of the counter-traction band. (Continued in Figs. 822, 823.)

Dangers.—In this connection it is especially important to condemn the old method of applying emergency splints for the first few days and waiting until the subsidence of swelling before attempting reduction. The

chief argument for this method has been that the application of retentive apparatus before the development of swelling is unsafe. This point is not

822



823

FIGS. 822 and 823.—Reduction of a fracture of the leg by the traction method. (822) When the plaster has hardened, the traction bands are removed and the foot supported manually while the remaining portion of the plaster is applied. (823) Plaster completed.

well taken, as such danger may be avoided by splitting the plaster on opposite sides immediately after it has hardened. Immediate reduction and fixation in plaster have proved safe in the hands of a great many surgeons,

and in the opinion of the authors, the advantages of the method cannot be questioned.

When Indicated.—Manual closed reduction should be attempted in the large majority of simple fractures of the bones of the leg which are seen within 24 hours of the time of injury. The method is applicable in practically all cases when the tibia alone is injured. It is likewise indicated in all cases of fracture of both bones, except those with extensive comminution or when the fracture line is markedly oblique and there is no bony support to prevent recurrence of deformity even if approximation is obtained. Such cases are better treated by the traction method described later, as are also the cases of compound fracture.

Anæsthesia.—Complete anæsthesia is always desirable in order to obtain complete relaxation and insensibility, not only during the manipulation, but also during the application of the plaster cast.

The Technic of Reduction.—The manipulation itself usually consists of traction and counter-traction, with lateral pressure and counter-pressure on the fragments. In some cases the method of first angulating the fragments to secure approximation and locking of the ends, followed by straightening of the leg, is useful. Gentleness should be the rule, and one should always be on guard to prevent possible injury to the overlying skin.

Methods of Maintaining Alignment.—It is usually much easier to reduce the deformity than to maintain the correction during the application of the cast. Slight movement of the leg during this part of the procedure with alteration in the alignment is almost unavoidable and is the common cause of failure. This difficulty may be avoided by the use of one of the following methods:

1. TRACTION METHOD

The patient is placed in the dorsal recumbent position on a firm table, with the buttocks resting on the edge. The injured leg is held by an assistant, while the uninjured leg is supported on a chair. The ankle and foot are padded abundantly with felt or cotton, and a piece of flannel bandage about 3 metres long is tied about the ankle in the form of a clove hitch, leaving the ends long. The loose ends are then knotted about the assistant's hips so that by leaning backward he may exert traction on the leg, while at the same time supporting the foot in proper position with his hands (see Fig. 820). Counter-traction is provided by tying the patient's shoulders to the opposite end of the table or, as is frequently desirable because of the additional muscular relaxation which it secures, the knee may be flexed to a right angle and a wide bandage passed around the thigh just above the knee, the ends being left long and held by a second assistant, who stands at the head end of the table.

The fracture is reduced and traction and counter-traction exerted to maintain the position. Then, over an abundant padding of cotton, the

plaster cast is applied in sections (Fig. 821). The first section extends from the ankle to the groin, and when it has hardened, the foot is supported manually and the traction band about the ankle removed (Fig. 822).

824

825

FIGS. 824 and 825.—Reduction by the gravity method. (824) The knee is flexed over the back of a chair. Downward traction is exerted on the foot and in this position a sectional plaster casing is applied. (825) The first section extends from the toes to the knee. (Continued in Figs. 826, 827).

The foot section of the plaster is then applied, extending upward from the toes and solidly joined to the section previously applied (Fig. 823).

Warning should be given, in case additional traction bands are used, to make certain that they are entirely removed before the plaster has hardened. Otherwise they are likely to become imprisoned in the plaster and cause serious constriction of the foot or thigh. Paralysis of the sciatic nerve, sloughing, and other mishaps have followed the failure to heed this warning.

2. GRAVITY METHOD

The patient is placed in the dorsal decubitus with the hips drawn down to the edge of the table. The uninjured leg is placed on a chair. A second chair is selected whose back corresponds in height to the top of the table.

826

827

FIGS. 826 and 827.—Reduction by the gravity method. (826) The second section extends from the knee to the groin. (827) When these have hardened, the leg is supported manually, the chair is removed and the two portions of the cast connected by the application of additional plaster bandages.

This is placed close to the end of the table and facing it. The injured limb is then drawn over the chair so that the lower portion of the posterior surface of the thigh rests on the top, which should be padded, while the leg hangs vertically downward with the knee flexed to a right angle (Fig. 824). In this position the weight of the foot and lower leg provides the necessary traction and it is easy for an assistant to maintain the alignment by slight pressure on the foot. The flexed position of the knee secures muscular relaxation and favors reduction.

With the leg in position and the assistant holding the foot, proper alignment is secured and a sectional plaster cast applied over the usual cotton padding (Fig. 825). The first section includes the leg from the toes to the knee, the second includes the thigh from the knee to the groin. When these have hardened, the chair is removed and the leg supported manually, while a third section is applied covering the knee and joining the two previous sections (Fig. 826).

3. POSTERIOR SPLINT METHOD

This method is useful in preventing sagging or posterior angulation of the fragments during the application of the cast. A wooden splint, long enough to extend from the heel to the upper end of the thigh, is cut out to conform as nearly as possible to the outline of the leg (Fig. 828). It is padded abundantly with sheet wadding, the padding being arranged in a manner to cause slight flexion of the knee and remove all possibility of pressure upon the heel.

Following reduction of the fracture the position is maintained by manual traction, while the splint, which has been previously prepared and padded, is applied to the posterior surface of the leg and fixed with adhesive strips or bandage (Fig. 829). The leg is now enveloped in cotton wadding and, while an assistant supports it with one hand on the foot and the other hand on the end of the splint, plaster bandages are applied encircling both the leg and splint and extending from the toes to the groin (Fig. 831). The splint remains inside the cast, but causes no discomfort or other difficulty if it has been properly applied.

After-treatment.—When plaster fixation is employed in a case of recent fracture, it should be the invariable rule to split the cast lengthwise on opposite sides as soon as it has hardened. The two halves should then be fixed together with buckle straps or bandage. This is to allow room for expansion in case of swelling. The condition of the circulation can be gauged quite accurately from inspection of the toes and this should be carefully watched during the first two days, and the cast, if necessary, loosened.

Suspension.—The leg should be elevated on pillows or suspended from an overhead frame by means of weights and pulleys. The latter is the better method and adds much to the comfort of the patient by allowing greater freedom of movement in bed (Fig. 832).

Roentgenological Examination.—Following the reduction and application of the plaster, new roentgenograms should be made in the antero-posterior and lateral planes. If the position is satisfactory, the cast is left untouched for four to six weeks, at the end of which time it is well to apply a fresh cast on account of the decrease in the size of the leg.

Persistent Displacement.—If the position is not satisfactory, further correction is necessary. The measures to be taken in such a case will

FIGS. 828, 829, 830 and 831.—The posterior splint method. (828) A length of splint board is cut out to conform as nearly as possible to the shape of the leg. (829) With abundant padding, this splint is then applied to the back of the leg. By supporting both the upper and lower ends of the limb along with the ends of the splint, the position of the bones may be maintained and sagging prevented during the application of the cast. (830) The leg and splint are enveloped in sheet wadding. (831) The plaster casing is applied, including both the splint and the leg.

depend upon the type of displacement. If there is end-to-end approximation, but slight angular deformity, this may be corrected by the application of a new cast or by the procedure known as "wedging" (see Fig. 833).

Wedging.—The cast is cut through transversely over a little more than half its circumference at the level of the fracture, the uncut portion being left on the side of the apex of the deformity. Thin pieces of wood are then pushed into the slit on the open side of the angle and additional

FIG. 832.—Whenever possible, the plaster casing should be suspended, as this adds materially to the comfort of the patient. (Fracture Service, M. G. H.)

pieces are from time to time added, thus wedging apart the divided segments of the plaster, while the intact side serves as the fulcrum. In this way angular deformity may be corrected gradually and without pain. When sufficient correction has been obtained, the upper and lower segments of the cast are solidly joined by the application of one or two additional plaster bandages and the apparatus left for union to occur.

THE CONTINUOUS TRACTION METHOD

Purpose of Traction.— While the majority of cases of fractures of the bones of the leg are amenable to treatment by the reduction and fixation method, this does not meet the needs of all cases, and in them the traction method is indicated. Traction should be employed in conjunction with a Thomas splint, as in the case of fracture of the femur. This provides the

necessary means of fixation, along with complete exposure of the seat of fracture. Traction is effective in correcting deformity, because as the bones are drawn apart, the surrounding muscles and fascia are put under tension and thus tend to force the fragments back into position.

Indications.—Traction should be employed as the primary method of treatment in all cases of compound fracture except those with the most minute puncture wounds; also in the case of simple fractures attended by much comminution or in which, on account of the character of the fracture, there is little chance of obtaining correction by the reduction method. It

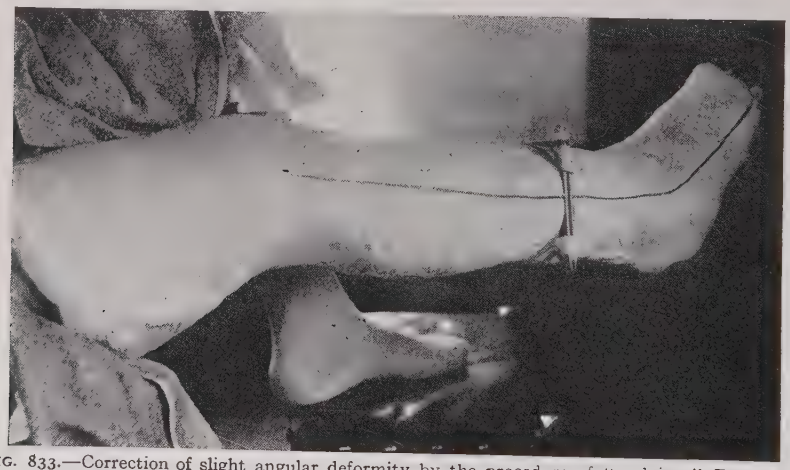
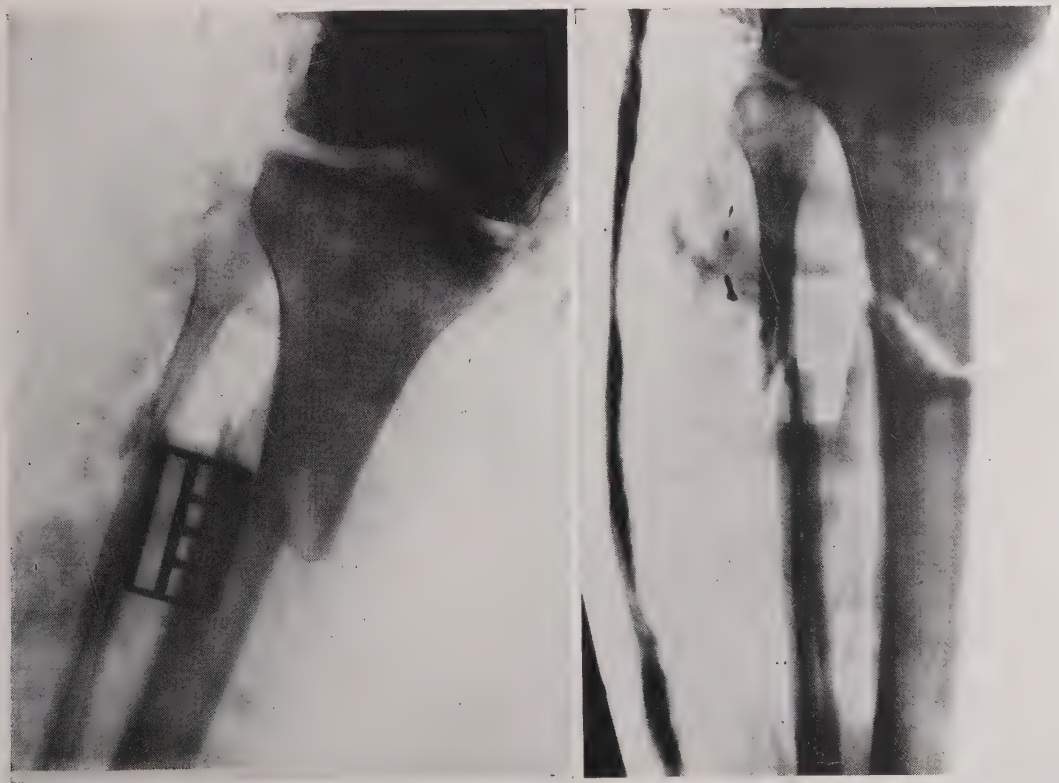


FIG. 833.—Correction of slight angular deformity by the procedure of "wedging." The cast is cut transversely on the open side of the angle at the level of the fracture. Thin pieces of wood are then inserted in the cut and additional pieces are added from time to time, thus wedging the fragments over into correct alignment. (Fracture Service, M. G. H.)

should also be the method of choice in cases with complete displacement which are not seen until 24 to 36 hours or more after injury. As a secondary or alternative method of treatment, traction is indicated in all cases where the reduction method has failed to obtain satisfactory alignment.

Methods of Obtaining Traction.—Traction may be obtained by the use of adhesive or flannel strips glued to the skin or by direct grasp of the bone by calipers or pins. Chief difficulty in the use of skin traction results from the small area of skin available below the level of the fracture. This is often inadequate to support the necessary weight, and loosening of the extension, blistering of the skin, and the formation of pressure sores are common sequelæ. It is necessary to attach the traction to as large an area of the foot as possible by the use of Sinclair's skate or the glued stocking.

Sinclair Skate.—This is a rectangular piece of wood about the length and width of the foot (Fig. 840). Its sides are notched in order to prevent displacement of the tapes which are tied across it. There is a longitudinal slot in its centre, in which slides a bolt, to which is fixed a transverse crossbar about ten inches in length. By changing the axis of this crossbar, which



834 835

FIGS. 834 and 835.—Fracture of both bones of the leg. (834) Unsatisfactory position following treatment by the reduction and fixation method. (835) Skeletal traction applied. Perfect alignment. (Fracture Service, M. G. H.)

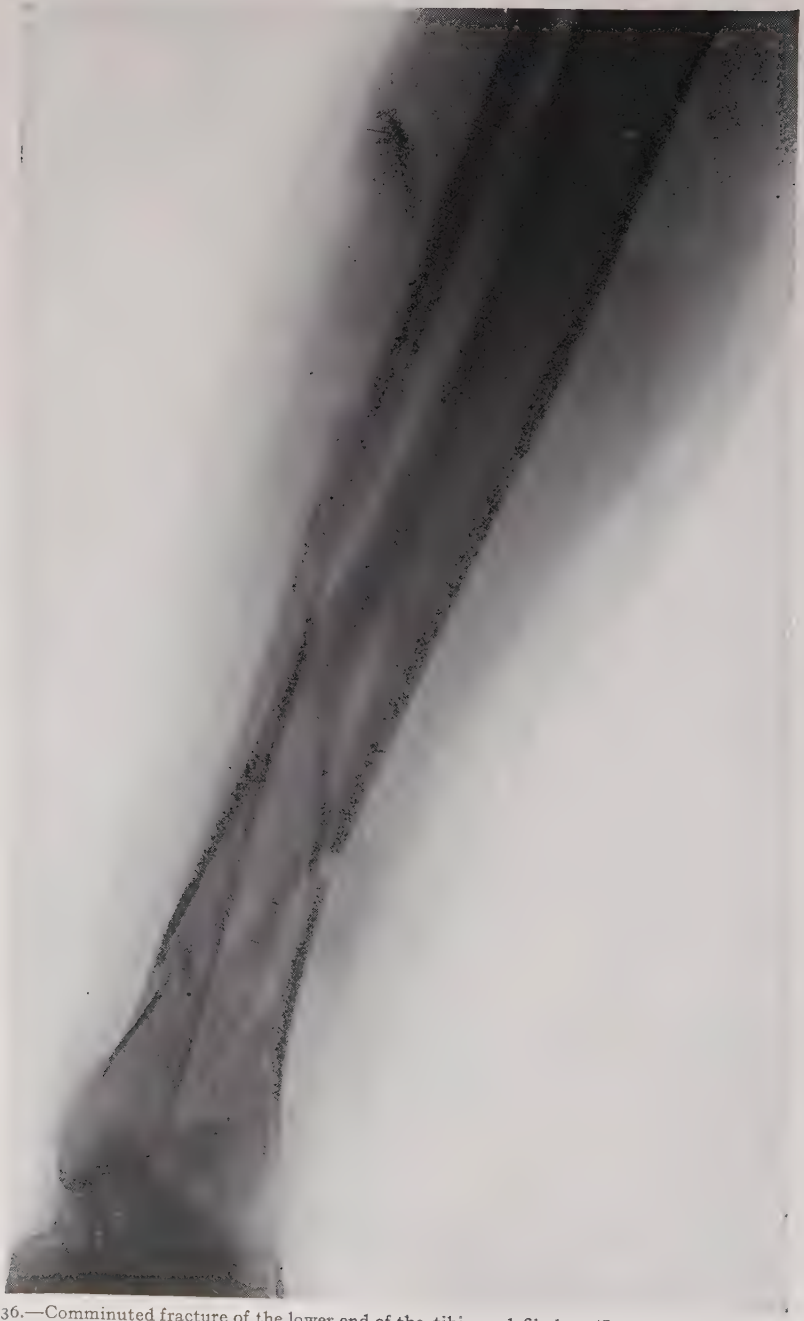


FIG. 836.—Comminuted fracture of the lower end of the tibia and fibula. (Same as Fig. 837.) Anterior view before reduction. (Fracture Service, M. G. H.)

rests on the side bars of the Thomas splint, the position of the foot may be changed at will. In applying the skate, a felt pad, to which tapes have

FIG. 837.—Comminuted fracture of the lower end of the tibia and fibula. (Same as Fig. 836.) Lateral view before reduction. (Fracture Service, M. G. H.)

previously been sewed, is glued to the plantar surface of the foot (Fig. 841). Strips of canton flannel with tapes attached are also glued to the dorsum. The skate is then applied and fixed in position by tying the tapes

FIG. 838.—Comminuted fracture of the lower end of the tibia and fibula. (Same as Figs. 836, 837.) Following reduction by the application of skeletal traction, in conjunction with a Thomas splint. (Fracture Service, M. G. H.)

across it (Fig. 842). The extension weight is attached to the skate by means of a cord loop fixed to the ends of the metal crossbar.

Glued Stocking.—A piece of splint wood of about the length and breadth of the foot is prepared and one of its surfaces covered with a layer of felt,

Fig. 839.—Comminuted fracture of the lower end of the tibia and fibula. (Same as Figs. 836, 837, 838.) Following reduction by the application of skeletal traction, in conjunction with a Thomas splint. (Fracture Service, M. G. H.)

which is fastened in place by adhesive plaster. The foot is painted with glue and covered with a smooth-fitting cotton sock. Openings are then cut in the toe and heel, through which the previously prepared splint board is passed, the felt pad lying in contact with the skin (Fig. 843). Three strong pieces of tape threaded on a blunt darning needle are then passed through the sides of the stocking between the felt pad and the splint board in the region of the toe, heel, and middle of the foot. The loose ends are

then knotted together, forming loops to which the extension weight is attached.

Skeletal Traction.—Skin traction is, however, generally unsatisfactory when heavy extension is required, as is frequently the case in fractures of the bones of the leg. For this reason, resort is being had more and more

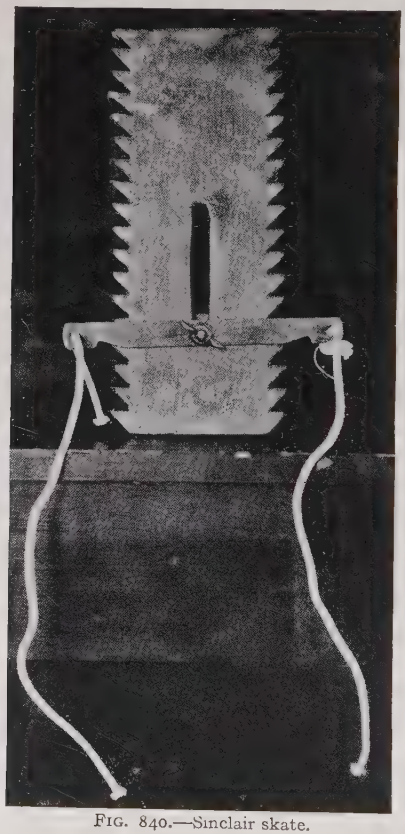


FIG. 840.—Sinclair skate.

frequently to direct skeletal traction. Several methods are available, such as the application of calipers to the malleoli or the passage of a pin through or over the os calcis. With the calipers there is danger of injury to the ankle-joint, while with the pin this risk is avoided. In the authors' hands, the latter method has proved safe and effective and has not been attended by any bad results, and it is, therefore, preferred.

Introduction of the Pin.—Aseptic precautions must be rigidly followed. The skin on either side of the heel is disinfected and a small incision made on the mesial surface at a point on a level with the top of the heel and anterior to the tendo Achillis. The pin is then introduced and passed over the top of the os calcis until the point is felt under the skin on the

opposite side. A second opening is then made, through which the pin is made to protrude until symmetrical lengths project on either side. Care should be taken to see that the pin lies fairly in the centre of the incision and does not drag on the edge of the skin, as this is apt to be painful. The method is similar if the pin is passed through the os calcis instead of over its top, only in this case the skin incisions are made at a lower level and a drill-pointed pin must be used with a removable handle, which gives the necessary purchase to force it through the bone. Either a divided

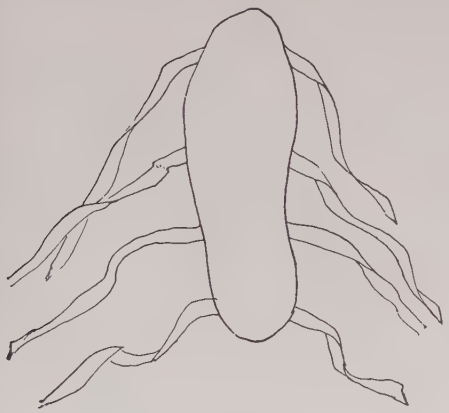


FIG. 841.—Felt pad with tapes attached which is glued to sole of the foot.

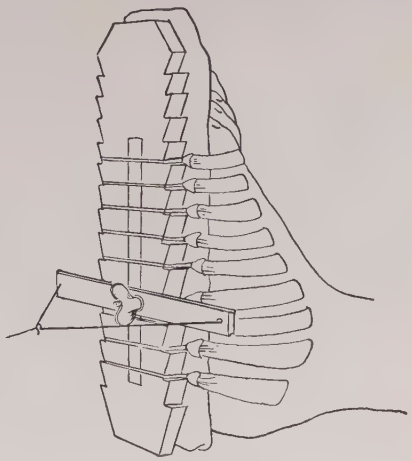


FIG. 842.—Sinclair skate applied.

pin (Steinmann) (Fig. 679) or a solid one (Hawley) may be used (Figs. 845, 846). The advantage of the divided pin is that it may be unscrewed in the middle and each half removed separately, thus obviating the risk of infecting the wound by pulling through it the contaminated pin-end.

After-care of the Pin.—This form of skeletal traction may be safely employed for a period of four to six weeks. The ends of the pin as they emerge from the skin openings are wrapped around with sterile gauze, and with proper protection it is unnecessary to change the dressings except at infrequent intervals. There is inevitably a little secretion about the skin openings and these have an unhealthy appearance, but they heal with astonishing rapidity when the pin is removed.

Connecting Up the Pin.—After the pin has been introduced and the dressing applied, it must be connected up with the Thomas splint. The method employed varies with the type of pin used. The Steinmann pin is provided with a jointed two-piece steel clamp, in shape resembling an ice tong. The ends of this fit over the ends of the pin, and the handles are connected by a cord, to which the extension weight is attached (see Figs. 847-849). With the Hawley pin a different arrangement is necessary.

The ends of the pin are threaded for the attachment of thumb screws (Fig. 846). Pieces of a strong malleable wire are twisted around the ends of the pin, a Sinclair skate with a plantar pad of felt is placed against the sole of the foot, and across this the wires are passed and fastened together (Figs. 850, 851). The pin is thus connected to the skate and the latter is in turn connected to the end of the splint in the usual manner. The use of the Sinclair skate has the advantage of permitting more accurate adjustment of the position of the foot than when the Steinmann pin and clamp are used. The latter has the advantage of simplicity.

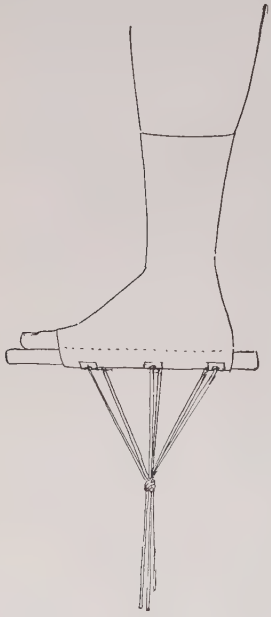


Fig. 843.—Glued stocking method of obtaining traction.

The Thomas Splint and Its Adjustment.—The Thomas splint is used in the same manner as in the treatment of fracture of the femur. The leg is supported by means of flannel or canvas slings fastened to the side bars. The desired alignment is obtained by altering the tension of these slings. The end of the splint is moderately elevated and fixed to the end of the bed, the ring is suspended from an overhead frame by means of a weight and pulleys, so that when the patient lifts himself in bed, the splint ascends with him and the ring retains its position below the tuberosity of the ischium. Moderate flexion of the knee is desirable both for the sake of comfort and also because it causes relaxation of the strong gastrocnemius-soleus muscle group. This may be obtained by bending the splint at the level of the knee before its application. An angle of 35 degrees is quite sufficient for this purpose. Special support of the foot is unnecessary with either of the above methods of skeletal traction, as the direct pull on the heel causes the foot to remain in the position of right-angle flexion.

Fixed and Sliding Traction.—Traction may be obtained by either the fixed or sliding methods. In the former the cords are connected directly to the end of the splint and the desired tension obtained by the "Spanish Windlass" method of twisting them with a stick. In the latter a pulley is fastened to the end of the splint over which the cord is passed and this is in turn connected with a weight. Twenty pounds is at first necessary, but when over-riding has been corrected, this may usually be decreased to ten pounds.

Roentgen Examination.—The real test of the sufficiency of the traction force is the correction of deformity as determined by roentgenograms. These should be made at the end of three to four days, and as often there-

after as readjustments in the apparatus are necessary to improve the position. A portable Roentgen machine is necessary for this purpose, as the patient cannot be moved without risk of altering the alignment of the leg.

After-treatment.— When satisfactory position is obtained, the apparatus should be left as nearly as possible undisturbed. Usually at the end of four to six weeks the union is sufficiently solid to permit the removal of the traction apparatus and the application of a plaster cast extending from the toes to the groin.

Physiotherapy.—The use of physiotherapy at as early a moment as possible is very important in hastening recovery. In the cases treated by the

FIG. 844.—Method of obtaining traction by passing pin across the top of the os calcis.

plaster fixation method, it is hardly practical to begin massage before the end of three to four weeks, as there is risk in removing even a portion of the cast before that time. With cases treated by the traction method, massage of the fracture site and of the muscles of the leg and thigh is possible from the very beginning. With either method, active movements of the knee and ankle should be permitted only when the callus is strong enough to allow the limb to be lifted without deformity, usually at the end of four to six weeks. Unsupported, active movement may be begun when solid union is obtained.

Time Required for Union.—The length of time required to obtain complete healing varies considerably with the type of fracture and its location. Transverse fractures take the longest time, as also fractures in the lower third, where the blood supply is poor. In some cases union is solid in six weeks; in others ten to twelve weeks are required. The presence of callus, the disappearance of abnormal mobility, and the absence of pain at the seat of fracture, when the bones are subjected to lateral strain, are signs that the union is firm.

Convalescent Stage.—However, protection is necessary for a considerable period after union is apparently solid. Refracture or the development of angular deformity are very real dangers when too early use is permitted. During this stage of treatment the patient may be permitted to

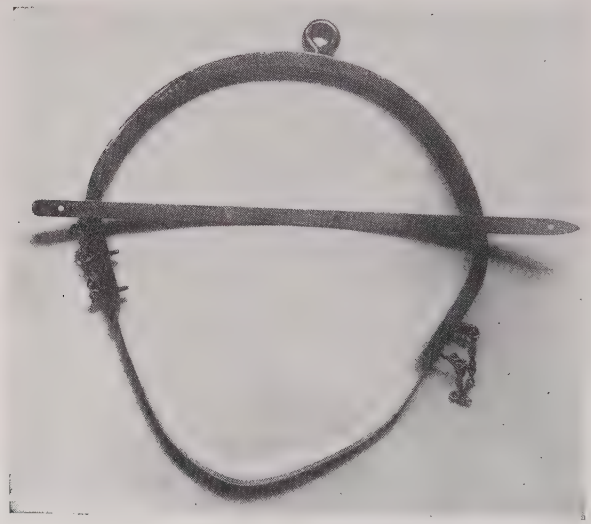


FIG. 845.—Finocchetti stirrup and tractor attachment for skeletal traction. The flexible blade is passed over the top of the os calcis.

walk with crutches without bearing weight on the injured leg, or special apparatus may be employed which protects the fracture against strain but permits partial weight-bearing.

Protected Weight-bearing.—The latter is both a better and safer procedure and is accomplished by the use of a short caliper brace or the

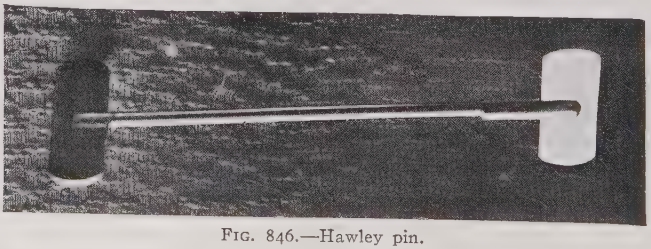


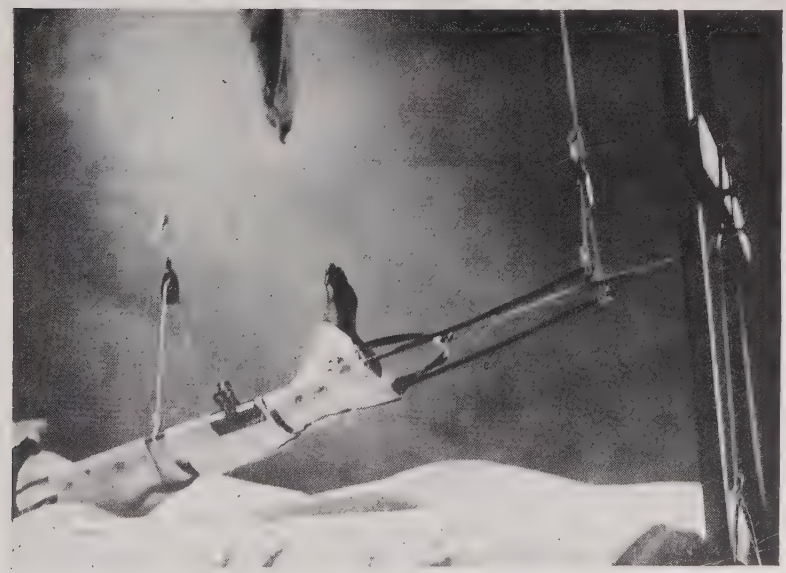
FIG. 846.—Hawley pin.

Delbet [1] type of plaster splint. The underlying principle with each is to utilize the shelving under surface of the upper end of the tibia as a bearing point, by means of which a considerable amount of the body weight is removed from the lower leg and transmitted externally to the ground. With accurately fitting apparatus, active use of the limb may be permitted,

[1] P. Delbet, *Bull. de l'Académie de Méd.*, January 5, 1915, Vol. 73, No. 1.

847

848



FIGS. 847 and 848.—Skeletal traction in fractures of the lower leg by means of Steinmann pin. Different views showing the method of connecting up the pin. (Fracture Service, M. G. H.)

even before the union is firm. This is of advantage because it counteracts bone atrophy and stimulates the circulation and thus hastens healing. It also activates the joints and exercises the muscles, and thus has an important effect in shortening the time of disability. The manufacture and correct adjustment of a short caliper brace require the services of an

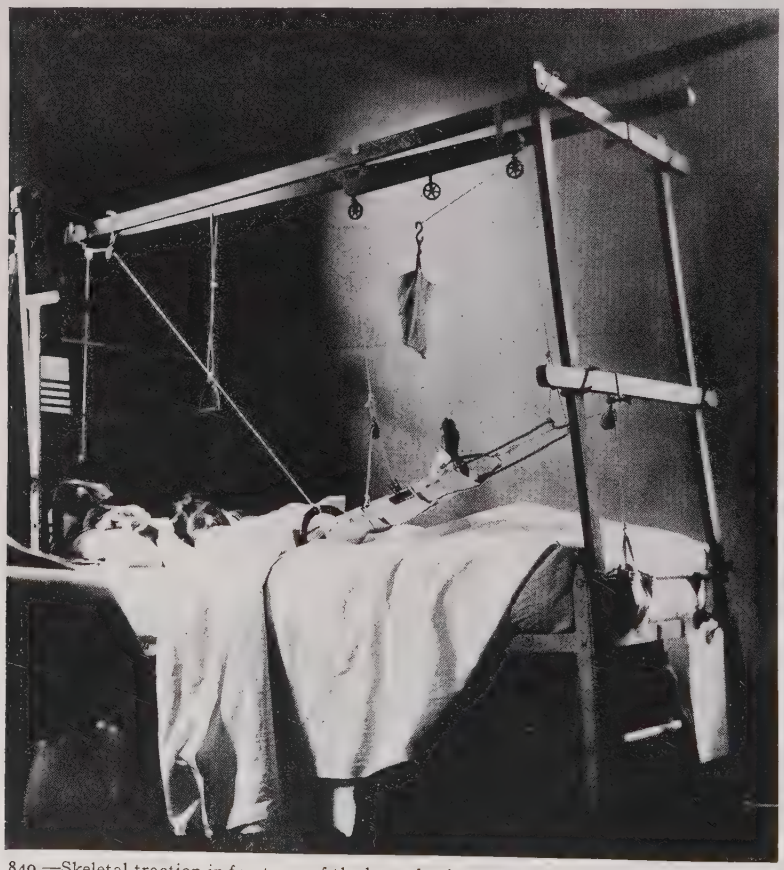


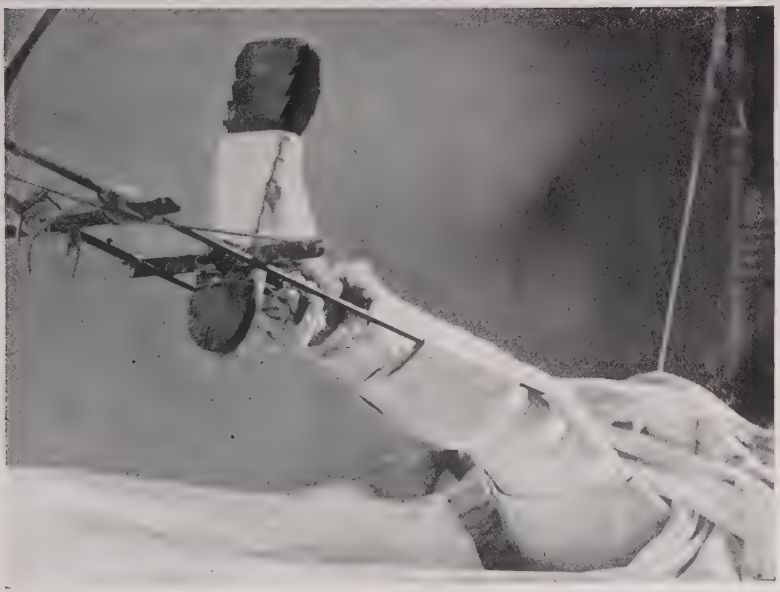
FIG. 849.—Skeletal traction in fractures of the lower leg by means of Steinmann pin. General view, showing the method of suspending the splint. (Fracture Service, M. G. H.)

expert surgical apparatus maker. The Delbet splint, on the other hand, may be quickly and easily made, but requires a certain amount of experience on the part of the surgeon.

Delbet Plaster Splint.—The Delbet splint may be made with the ordinary plaster bandages, which are folded into strips of the desired size and width, or the French method may be followed of previously folding and cutting the crinoline to the proper pattern (Fig. 854) and then, at the moment of application, immersing these strips in freshly prepared plaster paste of syrupy consistency. The plaster strips are applied directly to the

skin without the interposition of any padding substance, in order to obtain the closest conformation to the bony outline. The skin should first be

850



851

FIGS. 850 and 851.—Skeletal traction by means of Hawley pin. Note that in this case the pin is attached to the Sinclair skate by a wire which is twisted around its ends and that the traction is obtained from the skate itself. This case is one in which the reduction and fixation method was tried but failed. When traction was found necessary, the foot of the cast was removed and the pin inserted. Note that the cast still supports the thigh and leg in the Thomas splint. (Fracture Service, M. G. H.)

covered with a thick coating of vaseline. The first strip to be applied is the one which forms the collar below the knee (Fig. 855). This is long

enough to encircle the leg twice, but after the first turn is applied, the vertical side strips are placed in position, the upper ends being fixed by the second turn (Fig. 856). The lower ends of the side strips extend well down below the malleoli, and in the region of the ankle they are fixed by a circular turn with a fourth plaster strip. The ends of the latter may be carried spirally upward around the leg, in order to provide additional rein-

FIG. 852.—Skeletal traction by pin passing directly through the os calcis. (Fracture Service, M. G. H.)

forcement. The entire plaster is then covered with a circular gauze bandage and allowed to harden (Fig. 857). The upper end should be cut out on the posterior surface to allow flexion of the knee, and the lower circular band should also be trimmed if there is interference with ankle motion.

This apparatus, when properly made, is comfortable and yet gives considerable protection of the leg. Indeed, in certain types of transverse fracture it has been used by its inventor and other surgeons as the primary method of fixation following reduction, and early weight-bearing has been permitted without harm. However, this is a radical procedure and advisable only in the hands of experts.

Short Caliper Brace.—The short caliper splint consists of a leather collar with thin steel reinforcing band which encircles the leg below the knee and to which are attached two strong metal side bars which extend down-

ward to a socket in the heel of the boot. A leather cuff lacing in front encircles the leg at the level of the fracture and furnishes additional local support. An accurate fit is necessary, and to this end the brace should be made from a plaster mould of the leg (Figs. 858–861).

Duration of Use.—The use of a splint, such as either of the above, should be continued for about four weeks after the apparent complete consolidation of the fracture. At the end of this time unrestricted use may be permitted and but little further attention should be necessary.

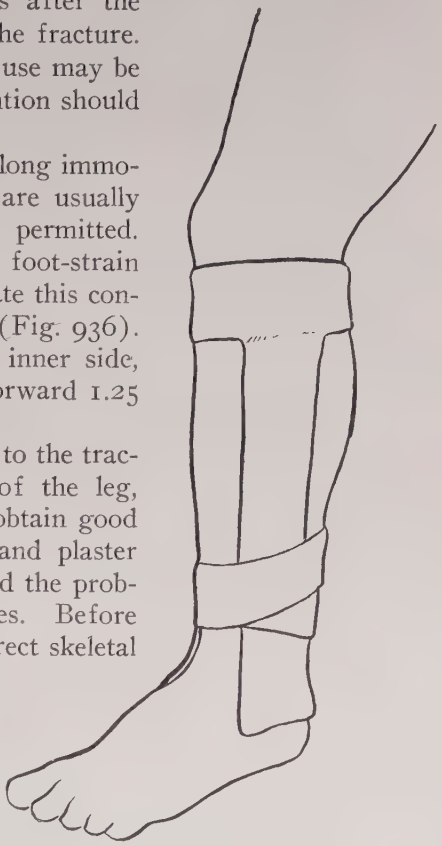


FIG. 853.—Delbet plaster cast.

Thomas Heel.—As a result of the long immobilization, the muscles of the foot are usually weak when weight-bearing is first permitted. Under these conditions, symptoms of foot-strain are common and it is well to anticipate this condition by the use of a Thomas heel (Fig. 936). It should be lifted six mm. on the inner side, and the anterior surface extended forward 1.25 to 2 cm.

Open Reduction.—The early resort to the traction method of treating fractures of the leg, whenever it has been impossible to obtain good alignment by the closed reduction and plaster fixation method, has practically solved the problem formerly presented by such cases. Before the introduction of the method of direct skeletal traction, open operative reduction and internal fixation were the only means at our disposal for dealing with cases of intractable displacement. On the special fracture service at the Massachusetts General Hospital during the last two years it has been the rule to employ skeletal traction in all difficult or complicated fractures of the bones of the leg, and since this method has been used it has not been necessary to operate on a single case of simple fracture for the purpose of improving alignment. With proper treatment open reduction will rarely be required. The only likely exception to this rule is a certain type of spiral fracture of the tibia, and in such cases the application of a Parham band may be indicated.

Malunion.—Old cases with malunion still persist, however, and much may be done to improve their condition. Angular deformity may be remedied by open osteotomy and correction of alignment, followed by

fixation in plaster. Usually both tibia and fibula must be sectioned through separate incisions. Cases with shortening require operative liberation of the fragments and the application of skeletal traction to correct the overriding. The ends of the bones should be freshened to facilitate union.

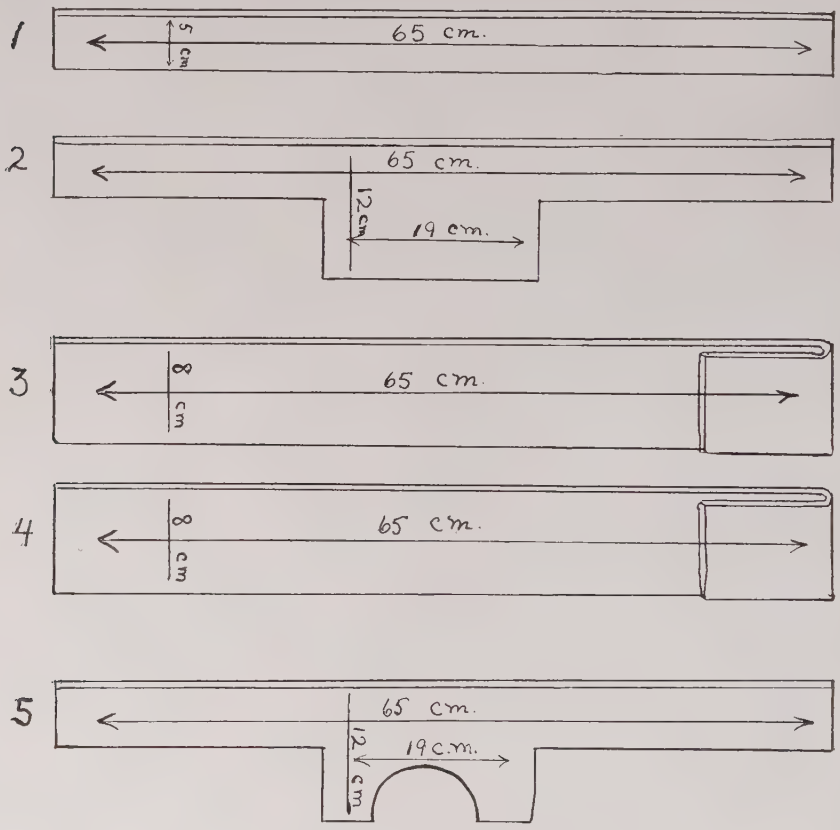
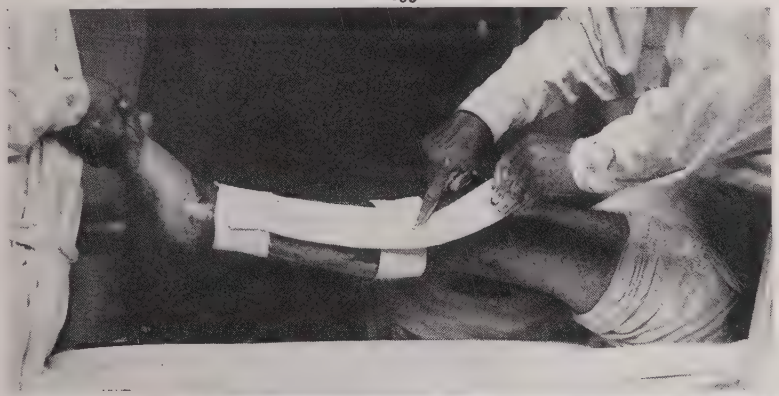


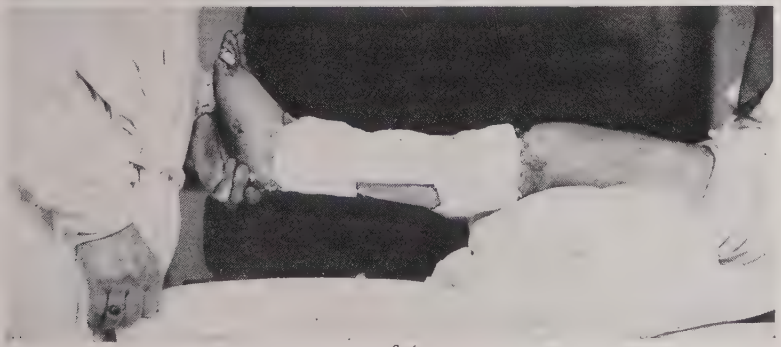
FIG. 854.—Pattern of plaster bandages to be used in making Delbet plaster splint.

Whenever possible, transverse section of the bones should be avoided, as a longer time is required for union and there is apt to be undue sacrifice of length.

Delayed Union.—Union in fracture of both bones of the leg is often considerably delayed. This is particularly likely to happen when the fracture lies at the junction of the lower and middle thirds. While incomplete reduction and imperfect immobilization favor its occurrence, these are by no means the only factors, as it is encountered frequently enough in cases where they can be eliminated. In such cases the condition is probably the result of insufficient blood supply to the lower fragment, as this portion of the bone is cut off from the nutrient artery, which enters the tibia above

855





856

857

FIGS. 855, 856 and 857.—Application of Delbet plaster. (855) Circular plaster cuffs have been applied to the upper and lower ends of the leg and now the lateral strips are being fixed in place. (856) The plaster strips in place ready to be held by application of a gauze bandage. (857) Plaster completed. (Fracture Service, M. G. H.)

the level of the fracture. The amount of blood which reaches the lower fragment through the vessels running in the capsule or entering through the periosteum is small and may be decreased by swelling of the soft parts or previously existing congestion and poor circulation. This view is substantiated by the roentgenological examination, which frequently shows the distal fragment to be markedly atrophied in comparison with the proximal one.

The condition should be treated by measures which are directed toward improving the blood supply, but without discontinuing the fixation of the

858 859 860

FIGS. 858, 859 and 860.—Short caliper brace. (858) View of brace and shoe. (859) Brace applied, anterior view. (860) Same, lateral view.

seat of fracture. Protected weight-bearing with a caliper brace or Delbet plaster splint best meets these indications, and in the authors' experience it has given gratifying results in very obstinate cases. The method should be tried for several months before deciding that a case of delayed union is in reality one of non-union.

Non-union.—Non-union requires operative treatment, with the insertion of a graft to stimulate bone repair. Wide exposure of the fracture site is best obtained by turning back a flap of skin on the mesial surface of the tibia. The sealed-over ends of the fragments must be thoroughly opened up by channeling down until the medulla is reached. Thin osteoperiosteal grafts may then be applied or, if fixation is desired, a sliding inlay or free transplant from the opposite leg may be employed. Immobilization is secured by the use of a plaster cast.

COMPOUND FRACTURES

Treatment of the Wound.—Careful débridement should be performed at the earliest possible moment in all cases of compound fracture except those with tiny puncture wounds, which may usually be treated with safety by the expectant method. Depending upon the time elapsed before

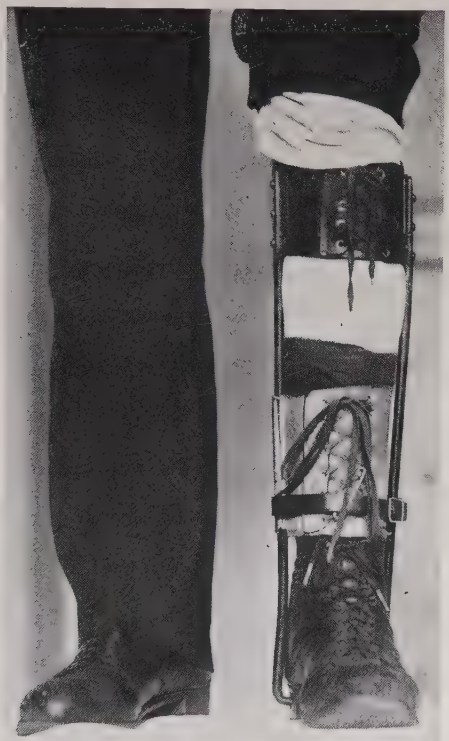
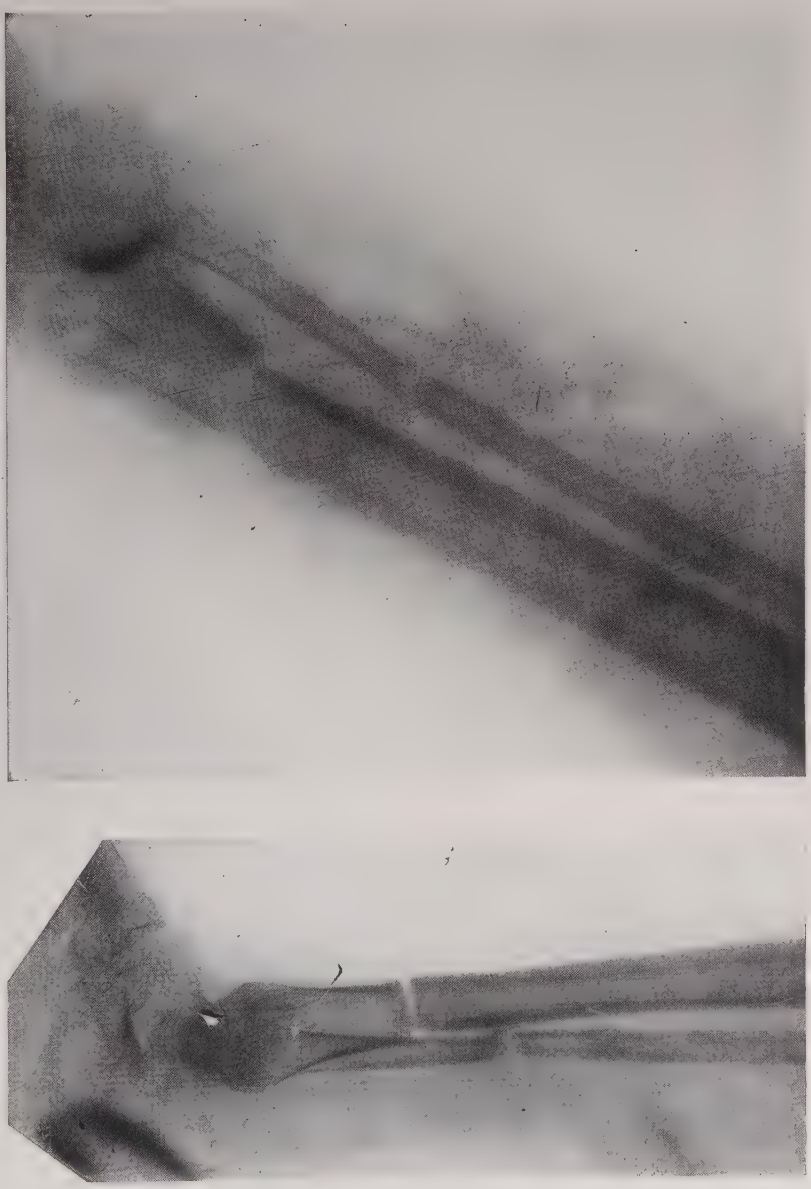


FIG. 861.—Short caliper brace applied in adult case of ununited fracture of both bones in the lower third. (Fracture Service, M. G. H.)

treatment is applied and the surgeon's estimate of how successful his efforts have been in the removal of soiled and devitalized tissue, the wound is either closed by primary suture or left open and tubes inserted for treatment by the Carrel-Dakin method. At the time of operation the ends of the bones should be approximated and the reduction maintained during the application of the dressing (Figs. 867–869).

Treatment of the Fracture.—The cases with tiny puncture wounds may usually be treated as simple fractures: that is, by immediate reduction and immobilization in plaster, the cast being immediately split and a window cut out over the wound to permit change of dressing and inspection. All others are best treated by the immediate insertion of a pin through

FIG. 862.—Malunited fracture of both bones of the leg. Before correction. (Fracture Service, M. G. H.)



FIGS. 863 and 864.—Malunited fracture of both bones of the leg. Following operative liberation of the fragments and the application of skeletal traction. (Fracture Service, M. G. H.)

865

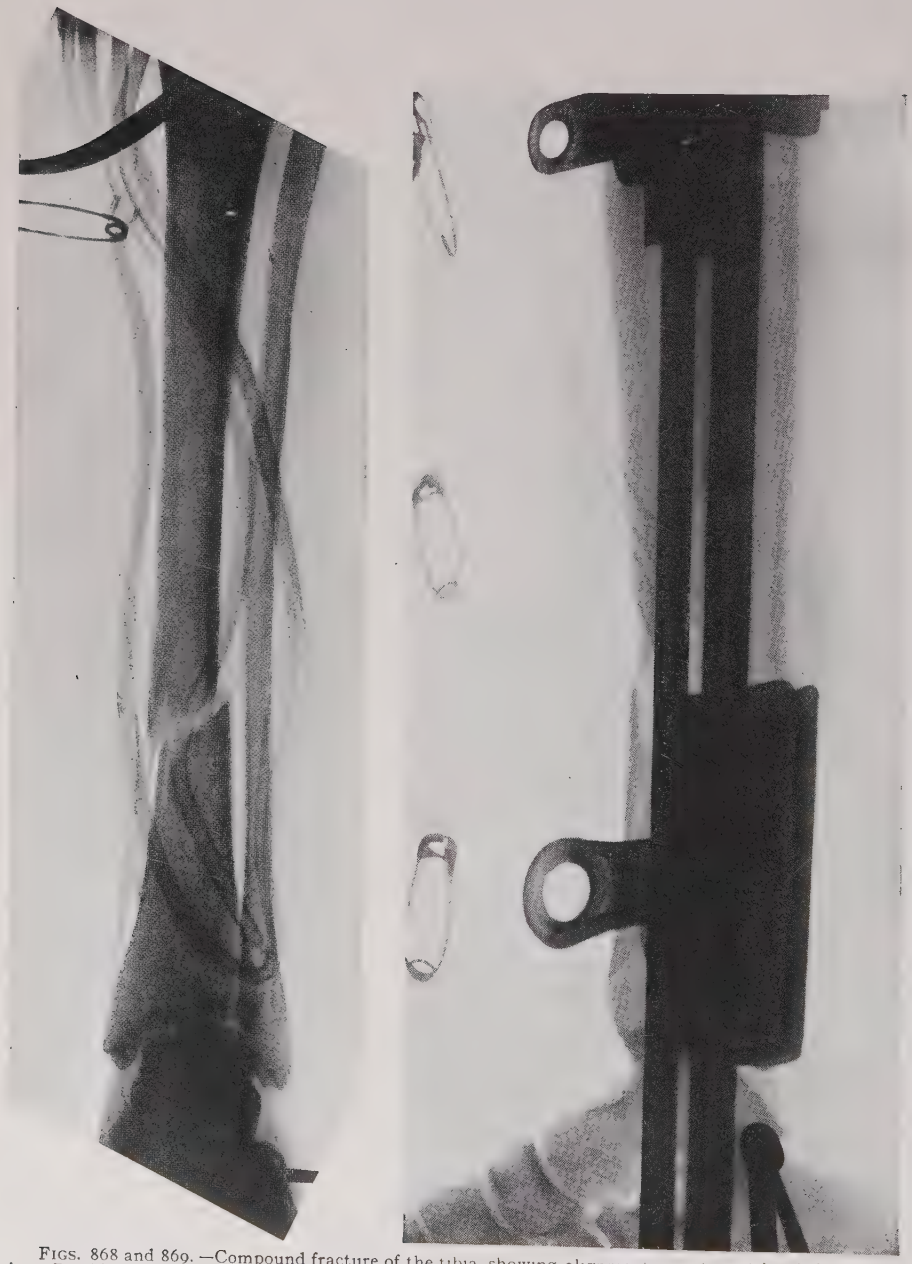
866

FIGS. 865 and 866.—Malunited fracture of both bones of the leg. (865) Plaster cast of leg, showing the deformity. (866) The dissected bones, showing fibrous union. (Warren Anatomical Museum.)

the heel for skeletal traction in conjunction with the Thomas splint (Fig. 867). This method permits complete exposure of the leg and inspection of the wound and is the only way in which alignment can be maintained in case infection should supervene. The pin causes no difficulty even if

FIG. 867.—Compound fracture of the leg being treated by skeletal traction. (Fracture Service, M. G. H.)

the fracture becomes infected, as has been demonstrated many times in the authors' experience, both in war cases and civilian practice. Secondary incisions for drainage may be made without disturbing the apparatus. If the wound remains clean, the leg may be transferred to a plaster cast at the end of about four weeks.



FIGS. 868 and 869.—Compound fracture of the tibia, showing alignment maintained by skeletal traction. By this method of fixation, wide exposure of the wound is possible and this permits the employment of the Carrel-Dakin method of treatment. The tubes in the wound are shown. (Fracture Service, M. G. H.)

CHAPTER XVIII

INJURIES IN THE REGION OF THE ANKLE

I. SPRAIN OF THE ANKLE

II. FRACTURES OF THE TIBIA AND FIBULA INVOLVING THE ANKLE-JOINT

1. Fracture by External Rotation of the Foot
2. Fracture by Abduction of the Foot (Pott's Fracture)
3. Fracture by Adduction of the Foot
4. Fracture by Posterior Displacement of the Foot

III. DISLOCATIONS OF THE ANKLE-JOINT

IV. COMPOUND INJURIES OF THE ANKLE

ANATOMICAL CONSIDERATIONS

Lower Ends of the Tibia and Fibula.—The bones entering into the formation of the ankle-joint are the lower ends of the tibia and fibula and the upper portion of the astragalus. The joint is in the form of a mortise, with the roof and mesial border formed by the tibia, while the fibula contributes only the lateral border and, therefore, does not function in the transmission of the body weight.

Both malleoli are important landmarks, as they are readily palpable by reason of their subcutaneous position. The inner malleolus is large and flat but less conspicuous than the smaller and more pointed external malleolus. The tip of the latter normally lies one finger's breadth below and posterior to the tip of the internal malleolus. The shaft of the fibula is exposed to palpation over a distance of 5 to 7 cm. above its enlarged lower extremity.

The Astragalus.—The astragalus consists of a body and a forward-projecting neck and head. Its superior articular facet is modelled to conform to the shape of the ankle mortise and is distinctly wider in front than behind. The head of the astragalus articulates with the scaphoid, while the under surface of the body forms with the os calcis the calcaneo-astragaloid joint. The ankle-joint proper is composed of two portions, the articulation between the tibia and fibula, and that between the ends of these bones and the astragalus. The tibio-fibular junction is more in the nature of a ligamentous union than a true articulation, although the synovial membrane of the ankle extends upward a few millimetres between the bones. The anterior and posterior tibio-fibular ligaments connect the lower ends of the bones at their anterior and posterior margins respectively, while the lower end of the interosseous membrane is thickened to form the interosseous ligament, and a special band known as the transverse ligament runs obliquely downward from the back of the tibia to the external malleolus. All of these ligaments are strong and the union is very firm.

The Tibio-astragaloid Articulation.—The tibio-astragaloid portion of the ankle-joint is strong from the conformation of its bony elements alone, but, in addition, the ligaments which retain the astragalus in the mortise are exceedingly thick and firm. The capsule takes origin from the lower margins of the tibia and the under surfaces of the malleoli and is attached to the astragalus about the margins of its superior articular surface. The anterior and posterior portions of the capsule are thin and weak, and it is here that swelling first appears when the joint becomes distended with fluid.

The Lateral Ligaments.—The internal lateral or deltoid ligament is a strong, wide band inseparable from the capsule and nearly 1 cm. thick at its point of origin. It passes downward from the internal malleolus to be attached anteriorly to the sustentacu-

lum tali and the scaphoid, its fibres mingling with those of the inferior calcaneo-scaphoid ligament, and posteriorly to the inner surface of the astragalus. The external lateral ligament consists of three fasciculi which pass in a radiating manner from the external malleolus. The anterior fasciculus runs forward to the astragalus, the middle one runs downward to the calcaneum, while the posterior one runs backward to the rear of the astragalus.

Movements of the Ankle-joint.—The superior surface of the astragalus and the inferior articular surface of the tibia are parallel, and in the frontal view lie in a horizon-

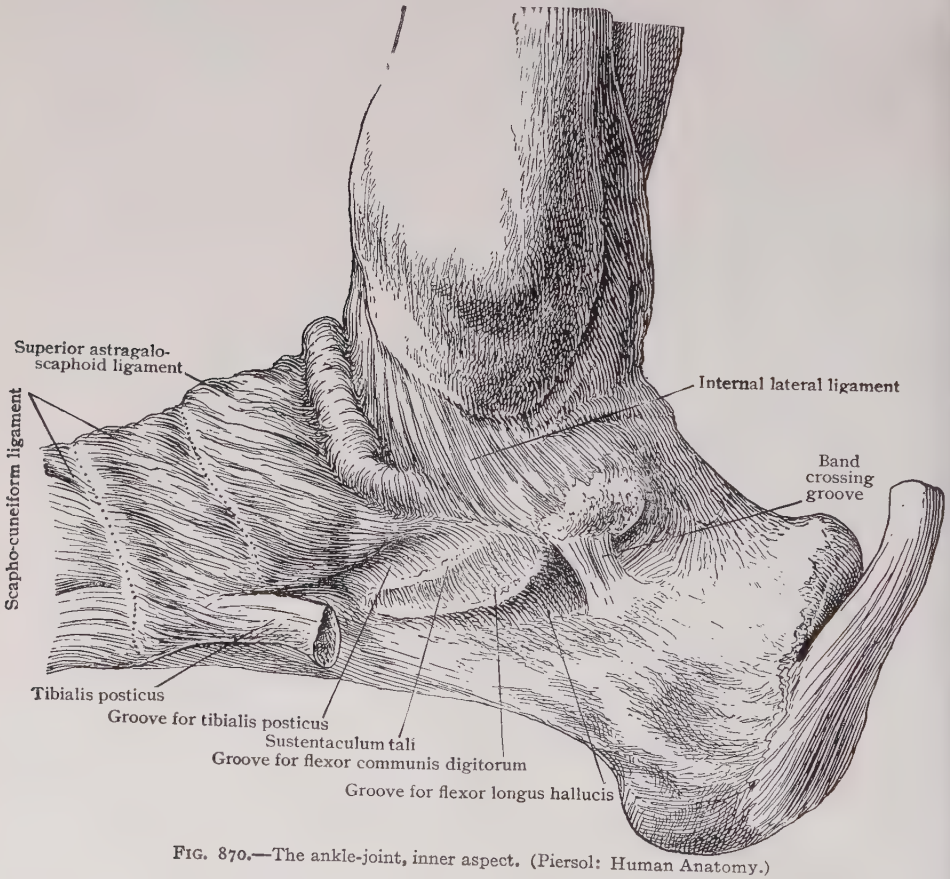


FIG. 870.—The ankle-joint, inner aspect. (Piersol: Human Anatomy.)

tal plane and perpendicular to the axis of the leg. Movement of the foot at the ankle-joint occurs practically altogether in an antero-posterior plane. Lateral movement is checked by the malleoli and the lateral ligaments. In plantar flexion the more narrow posterior portion of the articular facet of the astragalus is engaged in the mortise so that in this position it is less firmly locked than in dorsiflexion. The axis of motion is slightly oblique, so that in plantar flexion the foot points a little outward. Usually dorsi-flexion of the foot is possible to an angle of 70 degrees with the leg, and plantar flexion to an angle of 145 degrees, although there is considerable individual variation. Further movement in this plane is checked by the lateral ligaments and by contact of the astragalus with the margins of the tibia.

The amount of movement of the fibula on the tibia permitted by the superior and inferior tibio-fibular articulations is usually slight. It is of a gliding nature, forward

and backward, and apparently allows the lower end of the fibula to conform more closely to the astragalus in flexion and extension of the foot.

Lateral Movements of the Foot.—It should always be remembered that the lateral movements of the foot variously known as inversion, or supination, and eversion, or pronation, have their seat at the subastragaloid articulation and have no relation whatever to the ankle-joint proper.

Ossification.—The line of epiphyseal junction at the lower end of the tibia runs transversely across the shaft at a point 1.6 above the articular surface and lies above

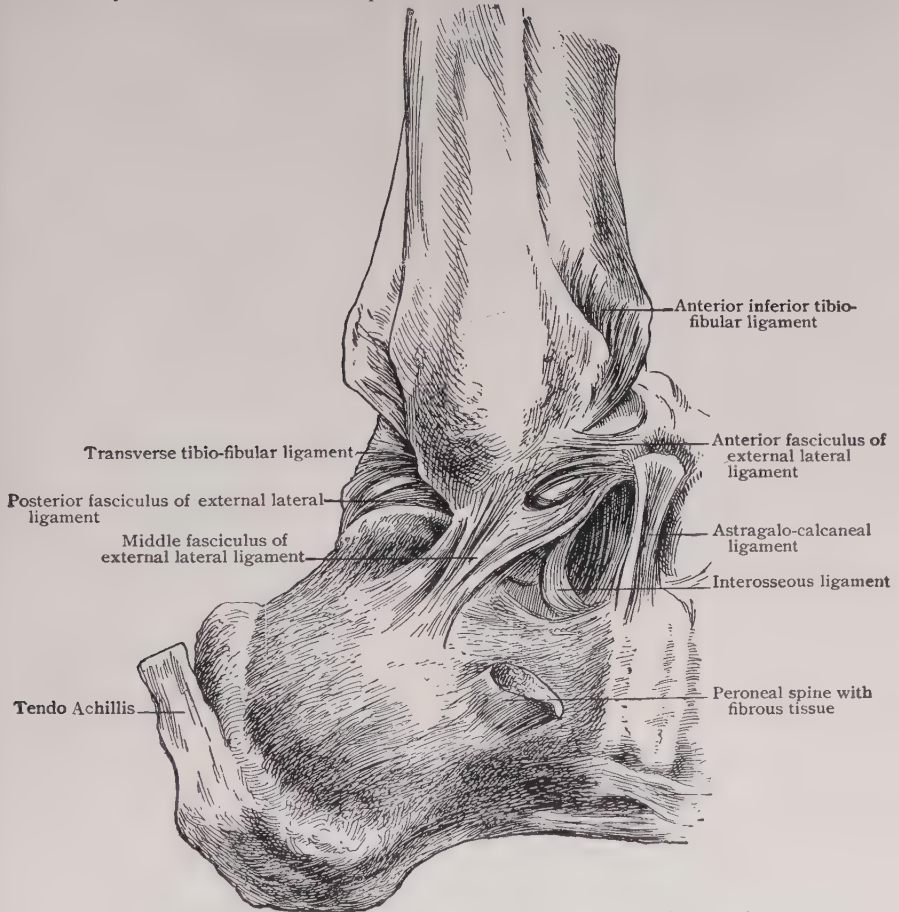


FIG. 871.—The ankle-joint, outer aspect. (Piersol: Human Anatomy.)

the point of capsular attachment. The epiphysis comprises the internal malleolus as well as the lower end of the shaft. It appears in the second or third year and unites at about the eighteenth year. The lower epiphysis of the fibula includes only the portion of the bone forming the external malleolus. It appears about the second or third year and unites with the shaft from the eighteenth to twentieth year. The line of junction is at the level of the articular surface of the tibia. The two epiphyses are for this reason seldom displaced at the same time (Figs. 873, 874).

Relations of the Tendons, Vessels, and Nerves.—In front of the ankle pass the extensor tendons, which, in order of arrangement, beginning at the inner side, consist

of the tibialis anticus, extensor longus hallucis, extensor longus digitorum, and peroneus tertius. They are enclosed in the anterior annular ligament. Posteriorly is the prominent tendo Achillis attached to the lower part of the posterior surface of the calcaneus. Proximal to its point of insertion the tendon is separated from the bone by the calcaneal bursa, which is sometimes the seat of an inflammation.

Lying behind the internal malleolus and enclosed by the internal annular ligament are the flexor tendons and posterior tibial vessels and nerve. Naming them in their position from before backward, these are the tibialis posticus, and flexor longus digitorum tendons, the posterior tibial artery, posterior tibial nerve, and the tendon of the flexor longus hallucis. Running directly downward along the posterior edge of the fibula and under the external malleolus are the tendons of the peroneus longus and brevis, the latter lying next to the bone. They are retained in position by the lateral annular ligament. The dorsalis pedis artery lies on the dorsum of the foot midway between

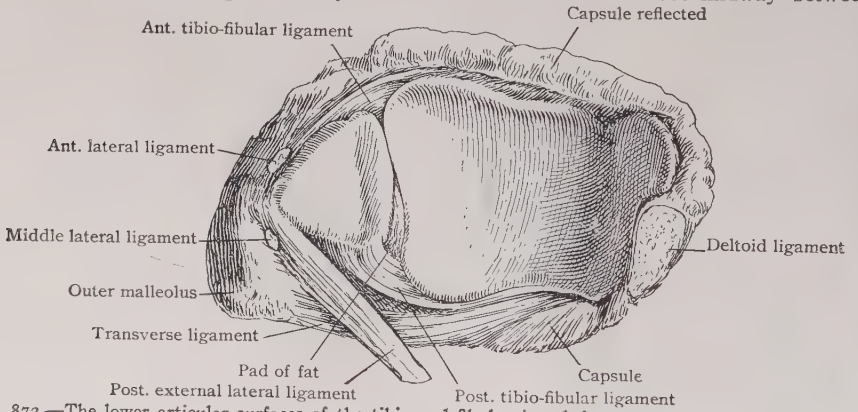


FIG. 872.—The lower articular surfaces of the tibia and fibula viewed from below, showing the anterior and posterior tibio-fibular ligaments and the transverse ligament. (Piersol: Human Anatomy.)

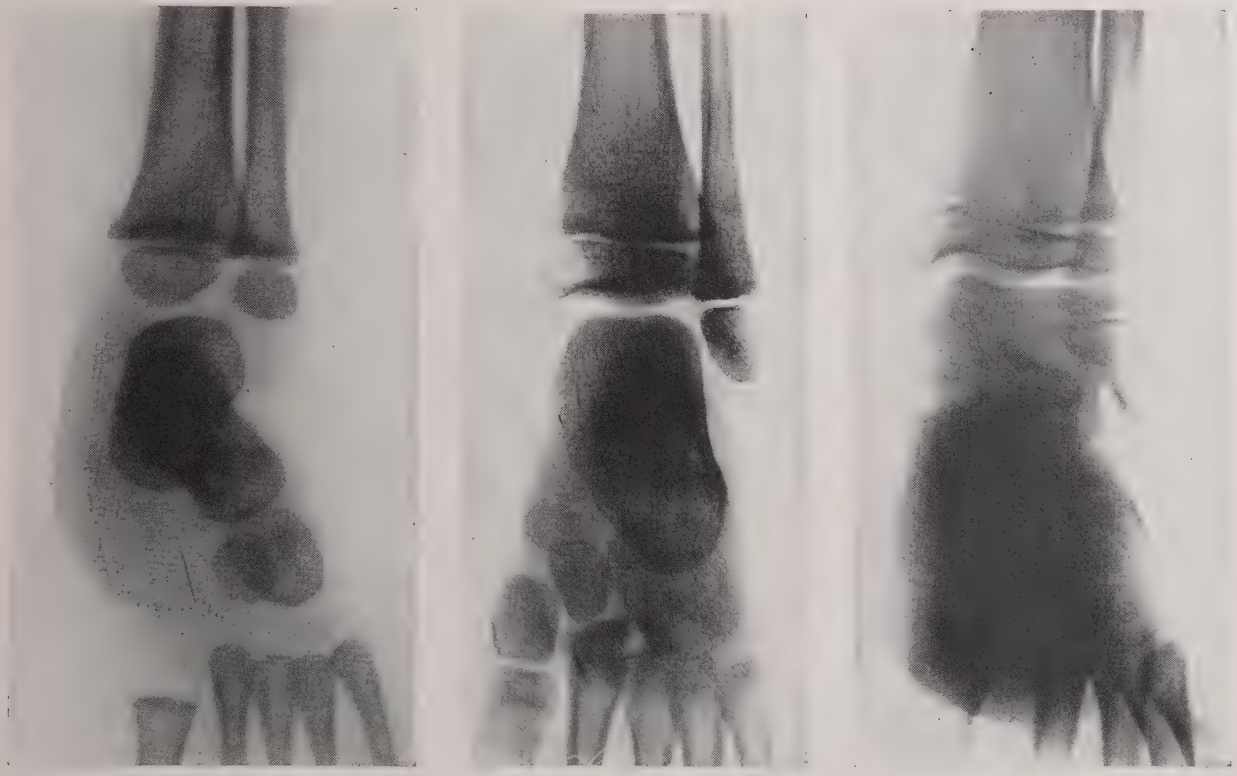
the two malleoli and to the outer side of the extensor longus hallucis tendon, where its pulsation may be readily felt.

Optimum Functional Position.—In case of ankylosis at the ankle-joint, the best function is obtained when the foot is fixed at an angle of about 95 degrees with the leg. If the subastragaloid joint is also involved, the foot should be in the position of slight inversion as well. From the standpoint of earliest return of function, the foot should be immobilized in the position of slight inversion with the arches well moulded and the ankle-joint at right-angle flexion.

I. SPRAIN OF THE ANKLE

Causation.—This is the most common injury of the ankle and is produced almost always by inversion of the foot. The ankle turns inward suddenly and unexpectedly and the external malleolus may touch the ground if the displacement is marked. The strain falls chiefly on the middle and anterior portions of the external lateral ligament, and these may be only slightly torn or partially or completely ruptured.

Diagnosis.—The patient gives a history of having turned the ankle or twisted the foot while walking or running. There is complaint of severe pain localized over the outer surface of the ankle and inability to bear weight upon the injured limb.



873 874 875

FIGS. 873, 874 and 875.—Development of the epiphyses at the ankle. (873) Age of two years. (874) Age of seven years, three months. (875) Age of eleven years.

Examination shows marked swelling, chiefly on the outer surface of the ankle. Extensive ecchymosis may develop later. All motions of the foot are possible, but inversion is particularly painful. There is generalized soreness over the outer side of the ankle, but the tenderness is most

FIG. 870.—Sprain-fracture of the ankle. Note the small chip detached from the anterior articular border of the tibia. (Edinburgh Royal Infirmary.)

marked at a point 1.25 cm. below and in front of the external malleolus. The bony prominences retain their normal relationship and there is absence of tenderness on pressure over the bone. Roentgenological examination is necessary to exclude the possibility of fracture and should be made as a matter of routine. Occasionally it shows a small chip of bone detached from the external malleolus, the so-called sprain-fracture (Figs. 876 and 877).

Treatment.—Complete fixation, as by the application of plaster of Paris, is usually contraindicated. It is to be remembered that the ligament is seldom completely ruptured, and repair of soft parts often goes hand in hand with use. There is a large amount of exudate, and with immobiliza-

tion the process of absorption is retarded, there is increased formation of scar tissue and delay in the recovery of function. On the other hand,

FIG. 877 (A, B).—Sprain-fracture of the tip of the external malleolus. Compare (A) the injured side with (B) the unaffected side.

if the ligament is protected so that it is relaxed and the torn portions held together, use will hasten the absorption of the exudate and reduce the time of disability.

Stirrup Adhesive Strapping.—Practically, this indication is met by the application of a firm adhesive plaster strapping. The foot is placed at right-angle flexion and everted, in which position it is held by a strip of bandage or adhesive fastened to the forefoot, the other end being

FIG. 878.—Method of applying stirrup strapping to the ankle-joint in case of a sprain of the external lateral ligament. (Foot everted.)

held by the patient (see Fig. 878). The surgeon then applies strips of adhesive about 2.5 cm. in width, which start on the inner side of the leg and run down and under the heel and up over the outer side of the ankle and leg. This so-called stirrup strapping should extend from the posterior portion of the heel forward as far as the front of the astragalus. In severe cases it should be several layers in thickness for the sake of additional support. The strapping should be fixed by the use of circular strips above the ankle, and a bandage should be applied over all.

After-treatment.—With such a dressing and the aid of crutches the patient should be encouraged to bear a certain amount of weight from the

very beginning. This may be difficult for the first day or two, but if the attempt is conscientiously made, the pain rapidly diminishes in amount, and after that progress is usually rapid. The strapping should be renewed every week for three or four weeks, at the end of which time a simple figure-of-eight ankle strap (see Fig. 938) or bandage may be substituted. Baking and massage are less effective physiotherapeutic agencies than frequently repeated active movements and are, therefore, unnecessary as long as the parts are actually used. In the usual case, recovery may be expected in three or four weeks. In the severe case, symptoms of mild degree may persist for six to eight weeks.

II. FRACTURES OF THE TIBIA AND FIBULA INVOLVING THE ANKLE-JOINT

Varieties of Fracture.—Fracture at the ankle involving the lower end of the tibia or fibula is a very common injury. It occurs very rarely in children, not infrequently in old age, but most commonly in the second, third, and fourth decades of life. Usually these fractures are grouped under the general designation of Pott's fracture or Dupuytren's fracture, without any attempt to distinguish the various types. Ashhurst and Bromer,[1] in a comprehensive study of the subject, have shown that this is not only inexact historically but illogical from both the pathologic and therapeutic standpoints. In reality, the group includes a great variety of different fractures, and while they all originate from a strain of the ankle, there are essential differences in the way this strain is applied. Recognition of the different types is of fundamental importance in understanding the various lesions and in planning the proper treatment.

Classification According to Mechanism.—All fractures of this general group occur as the result of indirect violence, the force being applied in a manner to cause abnormal bending or twisting movements of the foot. This causes strain to be brought to bear on the lower ends of the tibia and fibula and their ligamentous union, the effect being produced by a combination of leverage action from bony contact and arrachement from ligamentous pull. The structure of the ankle-joint provides the possibility of six different mechanisms, which may act singly or in combination with each other to produce injury. The astragalus may be internally or externally rotated in its mortise bed, or flexed inward or outward against one of the malleoli, or displaced forward or backward against the corresponding articular border. Forward displacement is, however, an unusual mechanism and one which is more apt to produce dislocation than fracture, and for this reason it will be considered under the former heading. Internal rotation likewise scarcely deserves to rank

[1] A. P. C. Ashhurst and R. S. Bromer, *Arch. Surg.* 4:51, January, 1922.

as a separate mechanism, since it merges with the movement of inversion (tibial flexion), and the force which would cause the former more easily

FIG. 879.—Fracture of the fibula by external rotation of the foot. Also fracture of the internal malleolus.

produces the latter. This leaves four main mechanisms, and the following groups of injuries, therefore, should be distinguished:

1. Fracture by External Rotation of the Foot
2. Fracture by Abduction of the Foot (Fibular Flexion)
3. Fracture by Adduction of the Foot (Tibial Flexion)
4. Fracture by Posterior Displacement of the Foot

1. FRACTURE BY EXTERNAL ROTATION OF THE FOOT

Mechanism and Pathology.—When the foot is extremely rotated on the leg or when, with the foot fixed, the leg is twisted inwardly with sufficient

880 881

FIGS. 880 and 881.—Fracture of the ankle by external rotation of the foot, lateral and anterior views. Note oblique fracture of the external malleolus, also separation of the internal malleolus.

force, the astragalus turns in the ankle mortise, and its anterior portion presses against the front of the external malleolus. A torsion fracture of the lower end of the fibula is produced, the fracture-line running obliquely upward and backward and separating the external malleolus. According to Ashhurst, this is the most common of all ankle fractures and is usually accompanied by only very slight displacement (Figs. 879 to 881).

If the force continues to act, the strain now falls on the internal lateral ligament, which either ruptures or pulls off a portion of the internal malleo-

lus. If the violence is extreme, there may result a fracture of the posterior margin of the tibia or rupture of the inferior tibio-fibular ligaments or avulsion of a small fragment from the lateral margin of the tibia, representing the point of attachment of these ligaments. With either of the latter two injuries, the lower ends of the tibia and fibula may be separated and the fibula may be fractured at its upper extremity (the neck) instead of at its lower end.

2. FRACTURE BY ABDUCTION OF THE FOOT (POTT'S FRACTURE)

Mechanism and Pathology.—When force is applied to the foot or leg in such a manner as to cause abduction of the ankle, such as follows a

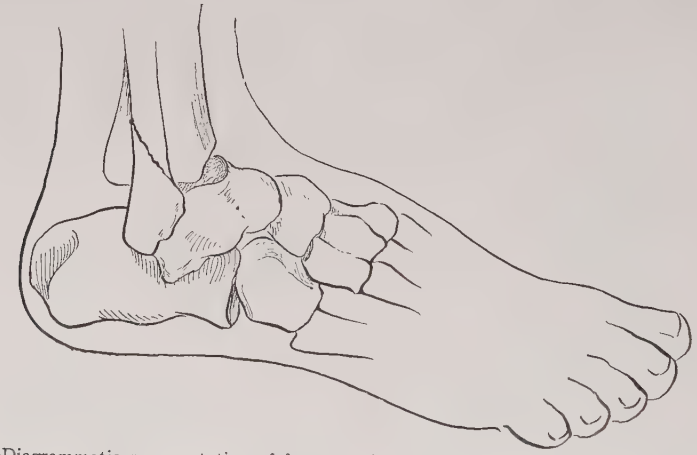


FIG. 882.—Diagrammatic representation of fracture of the fibula by external rotation of the foot. Note the oblique fracture of the external malleolus.

fall to the side when the foot is fixed or a blow on the outer side of the leg, strain is exerted primarily on the internal lateral ligament and secondarily on the external malleolus. The ligament may rupture or the internal malleolus, to which it is attached, may be torn off. This permits the astragalus to press outward against the external malleolus, which may break at its base, or by leverage, with the tibio-fibular ligaments providing the fulcrum, a fracture of the shaft of the fibula may be produced at a point two or three inches above the ankle (see Fig. 883).

On the other hand, the inferior tibio-fibular ligaments may rupture or a small portion of the tibia representing the attachment of the ligaments may be torn away, with resulting separation of the bones and widening of the ankle mortise. There is usually accompanying fracture of the shaft of the fibula in its lower third (Dupuytren's fracture).

Outward displacement of the foot is a constant feature and the injury is not infrequently compound. As a result of the widening of

the ankle mortise there is frequently associated with this fracture as a further step, a posterior dislocation of the foot. This is usually accompanied by a fracture of the posterior articular border of the tibia.

3. FRACTURE BY ADDUCTION OF THE FOOT

Mechanism and Pathology.— Adduction fractures of the ankle are produced by violent turning inward of the foot, as in a fall from a height

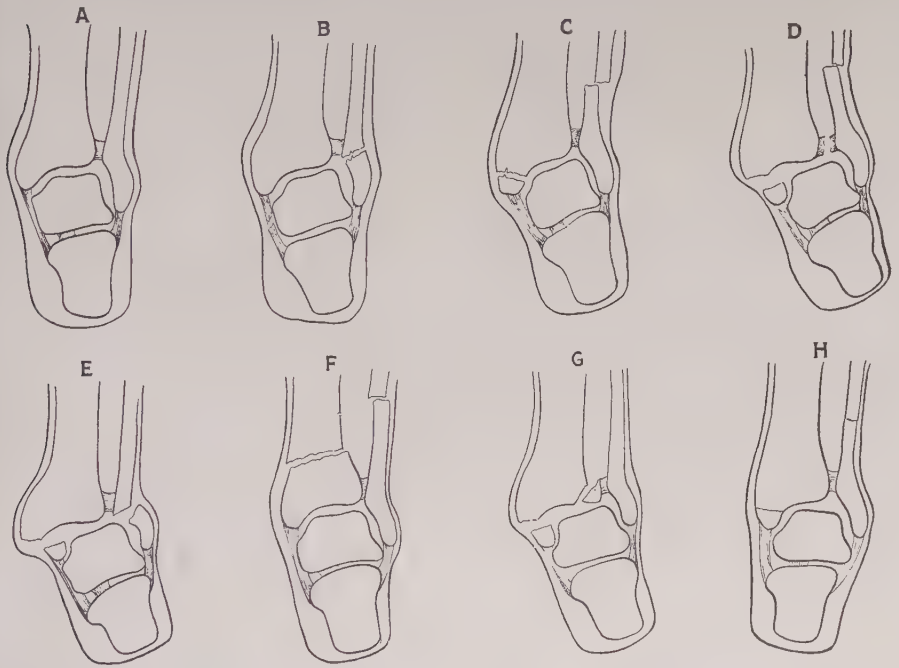


FIG. 883.—Mechanism of fracture by abduction of the foot. (A) Normal ankle. (B) Fracture of the external malleolus and rupture of the internal lateral ligament. (C) Fracture of fibula above the malleolus and avulsion fracture of the internal malleolus. (Pott's fracture.) (D) Same injury associated with a rupture of the tibio-fibular ligaments. (E) Bimalleolar fracture. (F) Supramalleolar fracture. (G) Avulsion fracture of internal malleolus and of external corner of tibia to which tibio-fibular ligaments are attached, usually associated with a fracture of the fibula at a much higher level. (Dupuytren's fracture.) (H) Reduction is to be accomplished by strong adduction of the foot.

with the foot inverted, or by falling to the opposite side when the foot is fixed. Strain is exerted on the structures of the ankle-joint in much the same way as in fracture by abduction, but they are involved in opposite manner and sequence (Fig. 884). Inward displacement of the astragalus is resisted primarily by the external lateral ligament and secondarily by the internal malleolus. The first structure to yield is the external lateral ligament, and if the violence is arrested at this point so that the injury proceeds no further, a simple " sprain of the ankle " is the only result. As a variant of this injury is the " sprain-fracture " of the ankle, in which the tip of the external malleolus, to which the ligament is attached, is torn away (Fig. 877).

If, on the other hand, the force continues to act, the astragalus is tilted in the ankle mortise, prying inward against the internal malleolus, while the lower articular surface of the tibia, bearing the body weight, is driven downward on the sharp mesial border of the astragalus. There

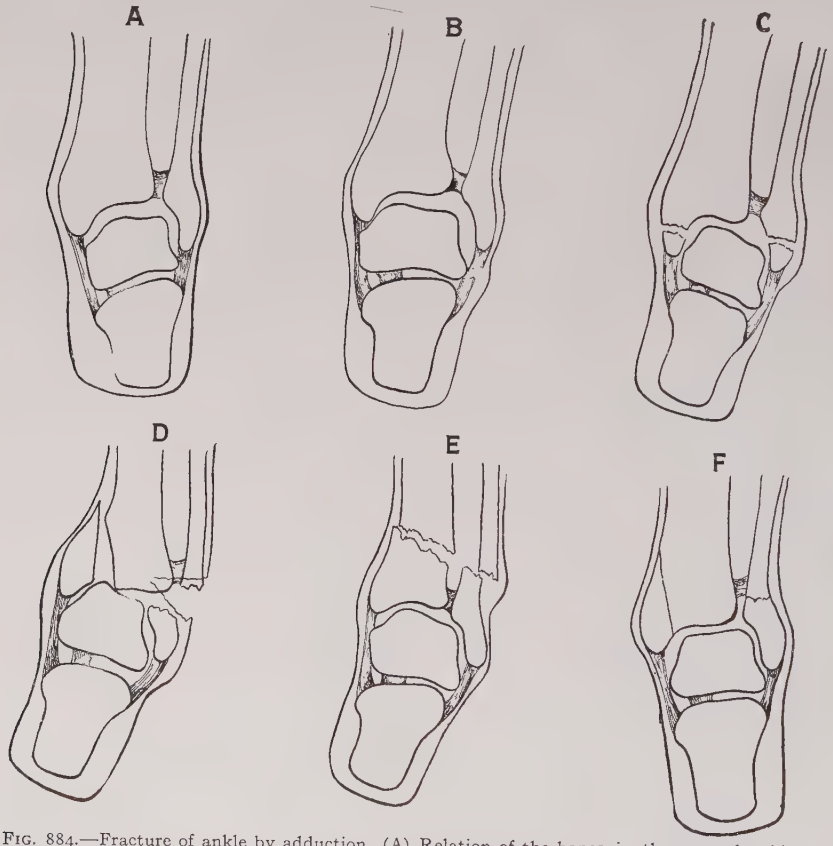


FIG. 884.—Fracture of ankle by adduction. (A) Relation of the bones in the normal ankle, frontal section. (B) Rupture of the external lateral ligament. (Sprained ankle.) (C) Bimalleolar fracture. (D) Vertical split of inner portion of tibia associated with fracture of the external malleolus, often compound. (E) Supramalleolar fracture. (F) Reduction of adduction fractures of the ankle by abduction of the foot.

may result a fracture of the internal malleolus or a vertical split through the tibia at its junction with the malleolus. There is rarely any injury of the inferior tibio-fibular ligaments or disjunction of the tibia and fibula. A supramalleolar fracture may result from the same mechanism, and occasionally a comminuted fracture of the lower end of the tibia. The foot is displaced to the inside and the injury may be compound.

4. FRACTURE BY POSTERIOR DISPLACEMENT OF THE FOOT

Mechanism and Pathology.—This injury may occur alone, but more commonly is associated with other fractures of the ankle, chiefly those produced by abduction or external rotation of the foot. It may be pro-

duced by force acting on the foot in an upward and backward direction, such as is represented by catching the heel on a stair and falling forward,

FIG. 885.—Adduction fracture affecting internal malleolus and fibula. (Fracture Service, M. G. H.)

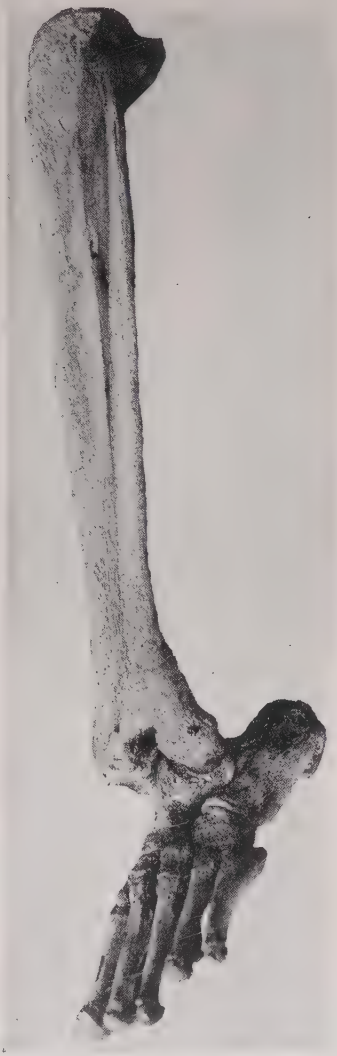


FIG. 886.—Specimen illustrating old unreduced fracture of the ankle from posterior displacement of the foot. (Army Medical Museum.)

or by violent plantar flexion of the foot, such as might result from tripping over a guy rope or other obstacle (Fig. 886).

The astragalus is driven backward and upward against the posterior articular margin of the tibia. A triangular piece of bone, including the posterior portion of the articular surface and a variable length of the

posterior surface of the tibia, and occasionally of the fibula, is broken off. The foot is usually displaced backward as a result of the removal of this posterior buttress, and the fragment is displaced with the astragalus. The dislocation of the foot may be partial or complete. This injury has been described by Cotton [2] and is frequently designated by his name.

SEPARATION OF THE EPIPHYSES

Causation.—Epiphyseal disjunction in the neighborhood of the ankle is an uncommon injury and occurs much less frequently than fracture.

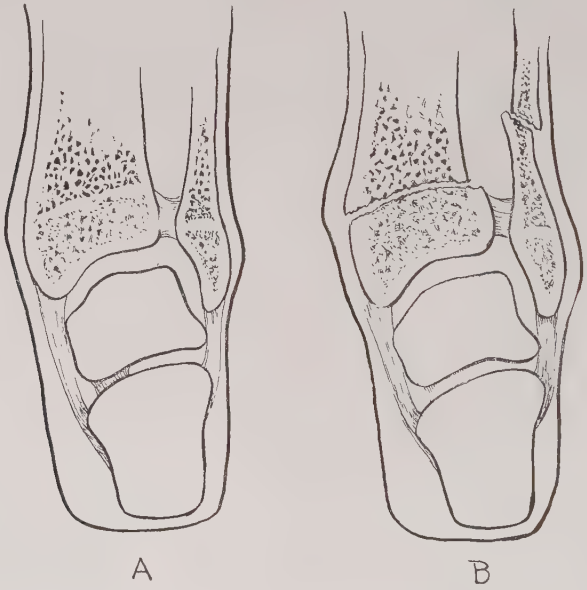


FIG. 887.—Separation of the epiphyses of the lower end of the tibia and fibula. (A) Frontal section through the ankle, showing normal relation of the epiphyseal line. (B) Separation of the lower tibial epiphysis associated with fracture of the fibula.

The usual age is between the eighth and fourteenth years. It is produced by the same type of violence that causes fracture of the ankle, the mechanism generally being one of abduction or adduction. The epiphyses of both the tibia and fibula may be separated together, but owing to their situation at different levels this is less common than separation of the epiphysis of the tibia associated with a fracture of the shaft of the fibula at the same level or a little higher. The treatment is the same as that of fractures in the region of the ankle.

DIAGNOSIS OF ANKLE FRACTURES

History of the Injury.—Fractures of the ankle are usually not difficult to recognize except in the milder cases, when they may be confused with sprains. An exact description of how the injury occurred is of great

[2] F. J. Cotton, *Journ. A. M. A.*, January 23, 1915, p. 318.

importance and can usually be obtained by careful questioning. With a knowledge of the mechanism of the injury and of the various lesions which it may produce, the interpretation of the findings on examination is much simplified.

Fracture with Displacement.—The presence of deformity, such as displacement of the foot either outward, inward, or backward, is easily recog-

FIG. 888.—Abduction fracture of the ankle. (Edinburgh Royal Infirmary.)

nized when present, and of itself suggests the nature of the injury. It must, however, be differentiated from a simple dislocation without fracture. Crepitus is often difficult to elicit and is not usually necessary for a diagnosis. Abnormal mobility of the foot at the ankle-joint is readily demonstrable in fractures of the more severe type.

Fracture without Displacement.—The cases without deformity or displacement are the most difficult to recognize from the clinical examination alone. Swelling develops rapidly and may mask the changes in the bony contour, but this of itself constitutes an indication of serious injury of the ankle. Limitation of motion or pain on movement also point to

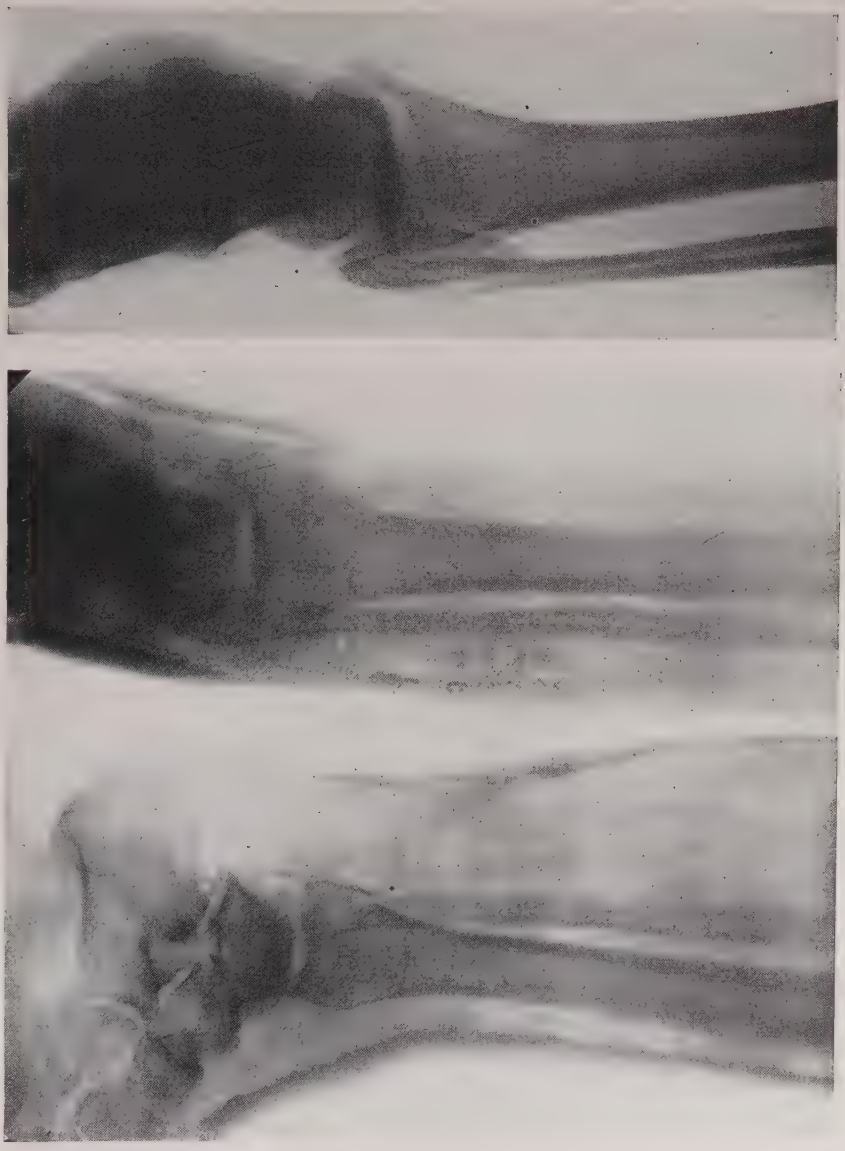
the presence of fracture. Reproduction of the movement that caused the fracture produces pain referred to the seat of injury.

Localized Tenderness.—Localized tenderness over the fracture-site is of great importance, because it is always present. Careful and systematic

FIG. 889.—Typical abduction fracture. (Potts.) (Edinburgh Royal Infirmary.)

search should be made for the points of maximum tenderness in the region of both malleoli, the lower third of the fibula, and over the front of the tibio-fibular junction. Differentiation between a ruptured lateral ligament and a fracture of the malleolus depends chiefly upon demonstrating whether the tenderness is greater over the bone or the soft parts below it.

Separation of the malleolus may be recognized by the presence of a sulcus at its base. There is often change in the normal relation of the

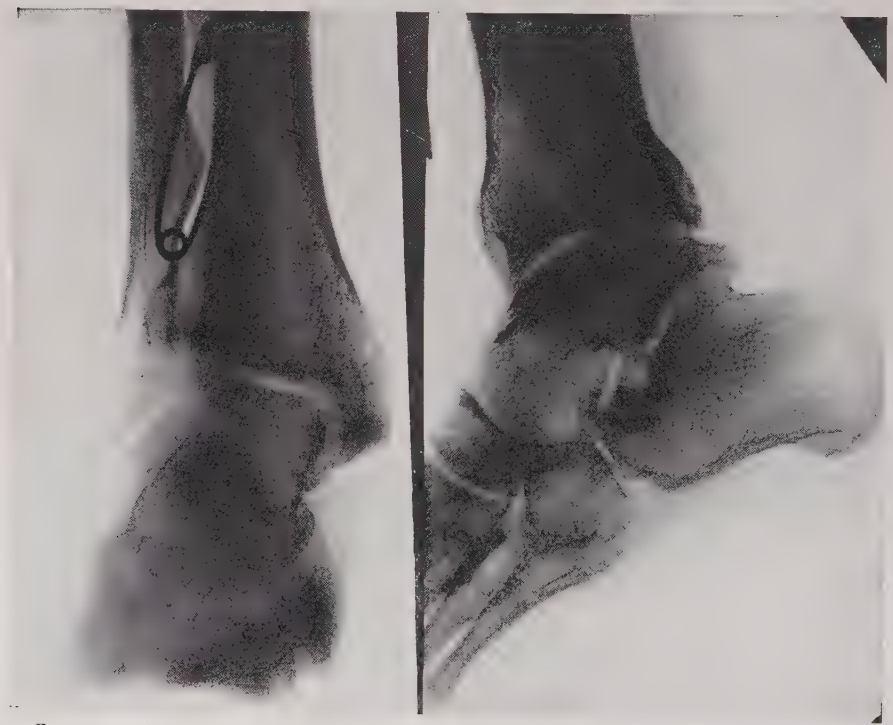


890 891 892

FIGS. 890, 891 and 892.—Oblique fracture of both malleoli from external rotation of the foot. (890) Before reduction. (891 and 892) Following reduction. (Fracture Service, M. G. H.)

malleoli, which can be demonstrated. Broadening of the ankle suggests separation at the tibio-fibular articulation. The length of the heel in relation to the forefoot must be carefully observed, as possibly indicative of dislocation of the foot.

Roentgen Examination.—Roentgenological examination should be made as a matter of routine in all injuries of the ankle. This constitutes a safe-



FIGS. 893 and 894.—Result of an old Pott's fracture with malunion. Note the everted position of the astragalus and the arthritic changes on its outer surface. The tip of the external malleolus lies at a higher level than the internal one. Pain and fatigue on use. (Fracture Service, M. G. H.)

guard, for lack of which it has happened all too frequently that a fracture has been treated as a sprain and the mistake discovered only when malunion has resulted. Even when the osseous character of the injury is recognized, the roentgenological examination renders an invaluable service by revealing the type of the injury, the extent of the damage, and the nature of the displacement—information which is essential for correct prognosis and treatment.

TREATMENT OF ANKLE FRACTURES

General Principles.—Fractures of the ankle are apt to cause long periods of disability and often result in permanent crippling, particularly when the patient's occupation is one which requires much standing.

These serious results may be prevented in large measure by attention to the following considerations:

1. Ankle fractures are intra-articular injuries and cause disruption of the joint. Displacement, if uncorrected, causes irregularity of the

FIG. 895.—End result of old fracture of the posterior articular border of the tibia with displacement of the foot. Malunion. It should have been possible to correct this rather easily in the beginning. (Edinburgh Royal Infirmary.)

joint surfaces and uneven bearing, and later, results in strain on use and painful arthritic manifestations. Complete anatomic replacement of the fragments is essential to good function.

2. Because of the articular involvement it is important, in order to prevent the formation of adhesions and the development of fibrous ankylosis, to begin mobilization of the joint by means of baking, massage, and active, supported movements at an early period.

3. On account of the great strain imposed on the ankle by the body weight, actual weight-bearing should not be permitted until the fracture is well consolidated, and then gradually and with protection.

4. Proper function of the foot is dependent upon the preservation of the normal weight-bearing lines. Splints should be applied in such a

FIG. 896.—Reduction and fixation method of treatment in abduction fractures of the ankle. The foot is held strongly inverted and dorsi-flexed during the application of the plaster casing.

manner as to support the plantar arches and prevent an equinus position (plantar flexion) of the foot. A Thomas heel or an arch support should be used when weight-bearing is first begun.

Manipulative Reduction.—It is possible to secure anatomical reposition of the parts by closed manipulative reduction in the great majority of ankle fractures. This procedure should be employed at the earliest possible moment, as the difficulties in the way of obtaining successful replacement gradually increase with the lapse of time. The manipulation consists of repeating the steps by which the displacement was produced, only in reversed direction and sequence. In order to do this successfully it is essential to know the mechanism of the injury.

Methods of Closed Reduction.—Complete anæsthesia is necessary. The leg should be supported by an assistant and the knee flexed to a right angle in order to relax the gastrocnemius muscle, the contraction of which often constitutes an obstacle to reduction.

1. FRACTURE BY EXTERNAL ROTATION

Draw the foot forward with one hand behind the heel while pushing backward on the tibia with the other, in order to correct possible posterior displacement. Then flex the ankle to a right angle and rotate the foot inward to its extreme limit. Fix the leg with the knee slightly flexed, the ankle at right-angle flexion, and the foot strongly inverted and inwardly rotated.

2. FRACTURE BY ABDUCTION

On account of the frequency with which these injuries are complicated by posterior displacement of the foot, begin with the movement of correcting this deformity, whether it is demonstrable or not. Pull the foot forward and downward in the position of slight plantar flexion, then flex to a right angle in order to prevent recurrence of the displacement. Then, while holding the foot by the heel and toes, strongly invert the foot to its extreme limit, maintaining the position of right-angle flexion, and pressing the malleoli together in order to correct separation of these bones at the tibio-fibular junction. Fix in this position with the knee well flexed (Figs. 889-896).

3. FRACTURE BY ADDUCTION

Posterior displacement of the foot in this condition is rare and no especial precaution is necessary with respect to it, unless its presence is demonstrated. The adduction deformity is corrected by strong eversion of the foot and abduction of the ankle. Fix the foot in this position with the ankle at right-angle flexion.

4. FRACTURE BY POSTERIOR DISPLACEMENT OF THE FOOT

Mention has been made of the frequent association of this injury with fractures by abduction and external rotation of the foot, and the manœuvre for its correction has been described in connection with these injuries. The foot should be pulled forward and downward in slight plantar flexion, with one hand behind the heel and the other making counter-pressure on the front of the tibia. The foot should then be forcibly dorsi-flexed as far as possible, in order to lock it in the articular mortise. Inability to dorsi-flex the foot to a right-angle position is a sure sign that the posterior displacement has not been completely corrected. Fixation should be applied holding the ankle in this position, the foot moderately inverted and the knee flexed nearly to a right angle.

Fractures without Displacement.—A considerable number of fractures of the ankle are seen which are not attended by any displacement. Anæsthesia and reduction are unnecessary in such cases, fixation alone meeting

FIG. 897.—Fracture of posterior articular margins of the tibia and fibula from posterior displacement of the foot. (Fracture Service, M. G. H.)

the indications. The foot should be gently flexed to a right angle and slightly inverted. If this is impossible because of pain and muscle spasm, the use of an anæsthetic is indicated.

Splinting.—Fixation is best obtained by the application of a plaster cast. The various special splints that have been devised for these fractures are seldom available at the right moment and even then are rarely of proper size. Plaster, if carefully applied, accomplishes exactly the same thing and is universally available. The leg should be evenly padded

FIG. 898.—Same as figure 897, following manipulative reduction and fixation in plaster. (Fracture Service. M. G. H.)

with sheet wadding, and special pads of felt should be placed over the bony prominences especially exposed to pressure. Cuffs of felt should encircle the toes and the leg at the top of the cast. In the case of fractures with displacement the cast should extend from the toes to the groin, the knee being fixed as well as the ankle. When the fracture is not attended by displacement, it is sufficient to apply a plaster boot extending from the toes to just below the knee.

The cast should be bivalved as soon as the plaster has hardened: that is, split completely through on opposite sides. The two portions may be retained in position by the use of buckle straps or bandage. In case of

circulatory disturbance the pressure may then be relieved by loosening the cast.

Roentgen Examination.—Roentgenograms should be made immediately after reduction, in order to determine if replacement has been accom-

Fig. 899.—Epiphyseal separation. Partial separation of the lower epiphysis of the tibia with greenstick fracture of the shaft of the fibula. (Edinburgh Royal Infirmary.)

plished, and should show the injured region in both the lateral and antero-posterior planes. Further exposures should be made previous to beginning weight-bearing, in order to demonstrate the progress of union, but otherwise are usually unnecessary unless the first reduction is unsuccessful and other measures to obtain correction are required.

After-treatment.—In case the position of the bones is shown to be satisfactory the patient should be kept recumbent for a period of one to

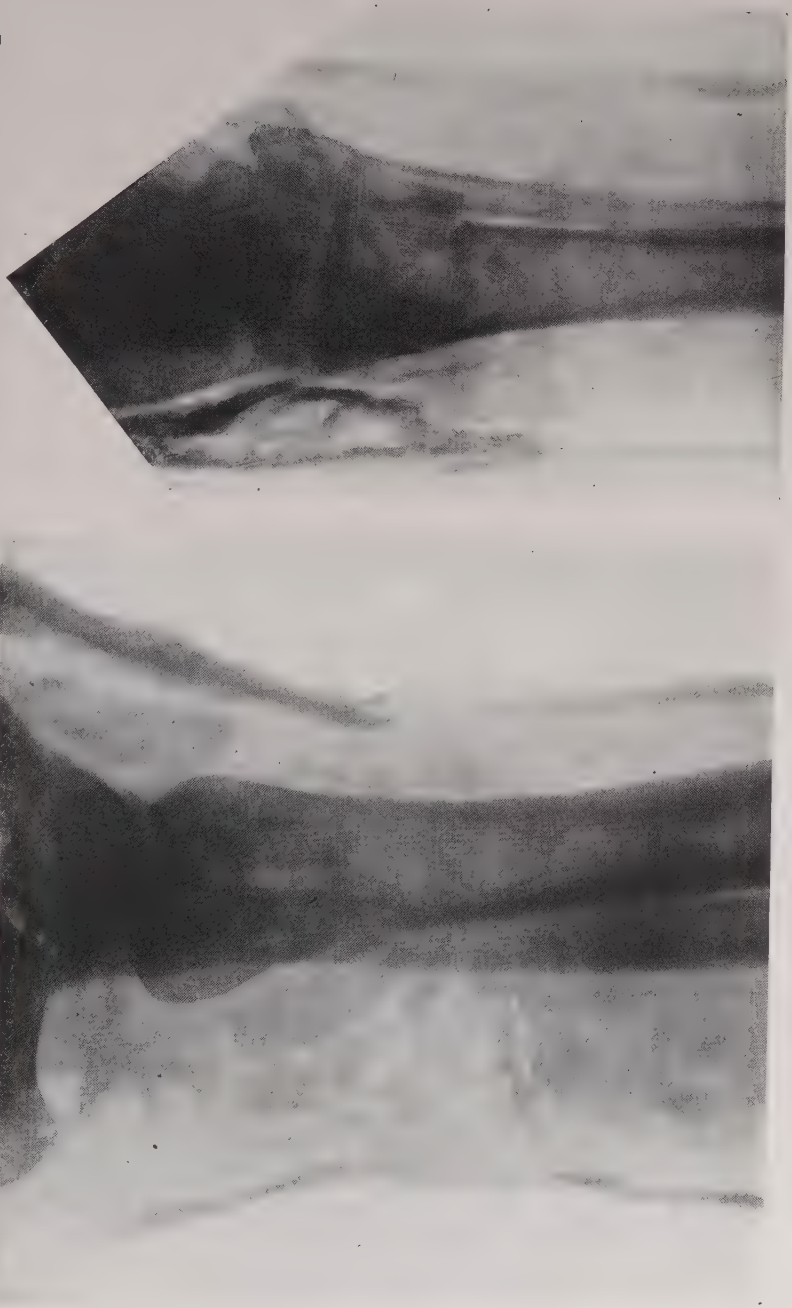
three weeks. The long plaster cast is heavy, and with the patient in the erect position it weighs on the foot and may cause a slight change in the alignment. Usually at the end of this period it is safe to permit the patient to walk with crutches, but weight should not be borne on the injured leg. At the end of three to four weeks the cast may be converted into a boot by

FIG. 900.—Partial separation of the epiphyses of both the tibia and the fibula. (Fracture Service, M. G. H.)

cutting away the portion above the knee, and free movements of the knee may be allowed. When the original injury is of mild character and only requires fixation by the use of a plaster boot, crutches may be permitted from the first.

Physiotherapy.—Physiotherapeutic treatment should be begun at the end of one to two weeks, depending upon the severity of the injury and the risk of recurrent displacement. The anterior half of the plaster is removed and the front of the leg is gently massaged. The toes and foot are moved and the muscles exercised to the extent permitted by the posterior portion of the cast. At the end of three weeks the limb may be gently lifted from the cast and a greater range of motion permitted, the foot being supported manually. The amplitude and strength of the movements are

FIGS. 901 and 902.—Supramalleolar fracture by external rotation of the foot. Before reduction. (Fracture Service, M. G. H.)



FIGS. 903 and 904.—Same case as shown in Figs. 901 and 902, following reduction. Replacement obtained by inversion and adduction of the foot. (Fracture Service, M. G. H.)

gradually increased from day to day, and at the end of four weeks the leg may be rested on a pillow and free motion encouraged.

Convalescent Treatment.—Union is usually solid in six weeks, and the cast may then be removed and the ankle protected by bandage only.

Fig. 905.—Old ununited fracture of the ankle with uncorrected abduction deformity of the foot.

Weight-bearing may be permitted at the end of six to eight weeks, using a loose-fitting, high shoe with Thomas heel (Fig. 936). The latter should be elevated six mm. on the inside and extended forward 1.25 to 2 cm. A stirrup strapping of adhesive plaster is necessary occasionally, as is also the use of a steel arch support. In fractures without displacement, weight-

FIG. 906.—Old malunited fracture of the posterior articular margins of the tibia and fibula from posterior displacement of the foot. (Fracture Service, M. G. H.)

bearing may be begun as early as four weeks after injury. Functional recovery should be complete in eight to fourteen weeks, depending upon the severity of the original injury.

Incomplete Reduction.—If satisfactory position is not obtained by the first manipulation, a second effort at reduction should be made as soon

as possible afterward. The chief obstacles to reduction in stubborn cases are the contraction of the gastrocnemius-soleus muscle group and occasionally the entanglement of the sharp end of a fragment in the fascia.

Skeletal Traction.—These difficulties may be overcome by a Z-shaped tenotomy of the tendo Achillis at the time of the second manipulation or

FIG. 907.—Lateral fracture dislocation of the ankle. (Fracture Service, M. G. H.)

by the application of continuous traction to the foot. The operation of tenotomy in adults often leads of itself to considerable disability, and the traction method is usually preferable. Skeletal traction should be used with a metal pin over the os calcis in conjunction with a Thomas splint. A heavy pull of 15 to 25 pounds should be used at first (see p. 670).

Open Reduction.— Operative treatment is indicated in cases with separation of the lower ends of the tibia and fibula which cannot be corrected by

closed reduction. This deformity causes widening of the ankle mortise and, if allowed to persist, results in considerable disability. The operation should be performed within the first two weeks and consists in exposing the tibio-fibular junction by a vertical incision over the front of the joint. The space between the bones is cleared of granulation tissue and the bones approximated. Fixation by means of a steel screw may or may not be required.

Old Malunited Fractures.—Disability when due to malunion of an old fracture may be considerably alleviated by operative treatment. Osteotomy of the malleoli with correction of deformity or clearing of the tibio-fibular junction with approximation of the bones and fixation by a metal or bone screw are the usual measures necessary. Proper alignment of the foot in relation to the tibia is the essential objective, and provided this is obtained, the position of the fibula may be ignored.

Non-Union.—This occurs usually from failure to obtain complete reduction of the deformity. Operative treatment is indicated and consists in freshening the ununited surfaces of the fragments and suturing them together with kangaroo tendon or chromic catgut. Thin osteoperiosteal grafts should be placed at the fracture-line to stimulate union. Prolonged fixation is required. Failure of the fibula to unite with the tibia following rupture of the tibio-fibular ligaments may be overcome by operative clearing of the tibio-fibular junction, approximation of the bones, and fixation by a bone or metal screw.

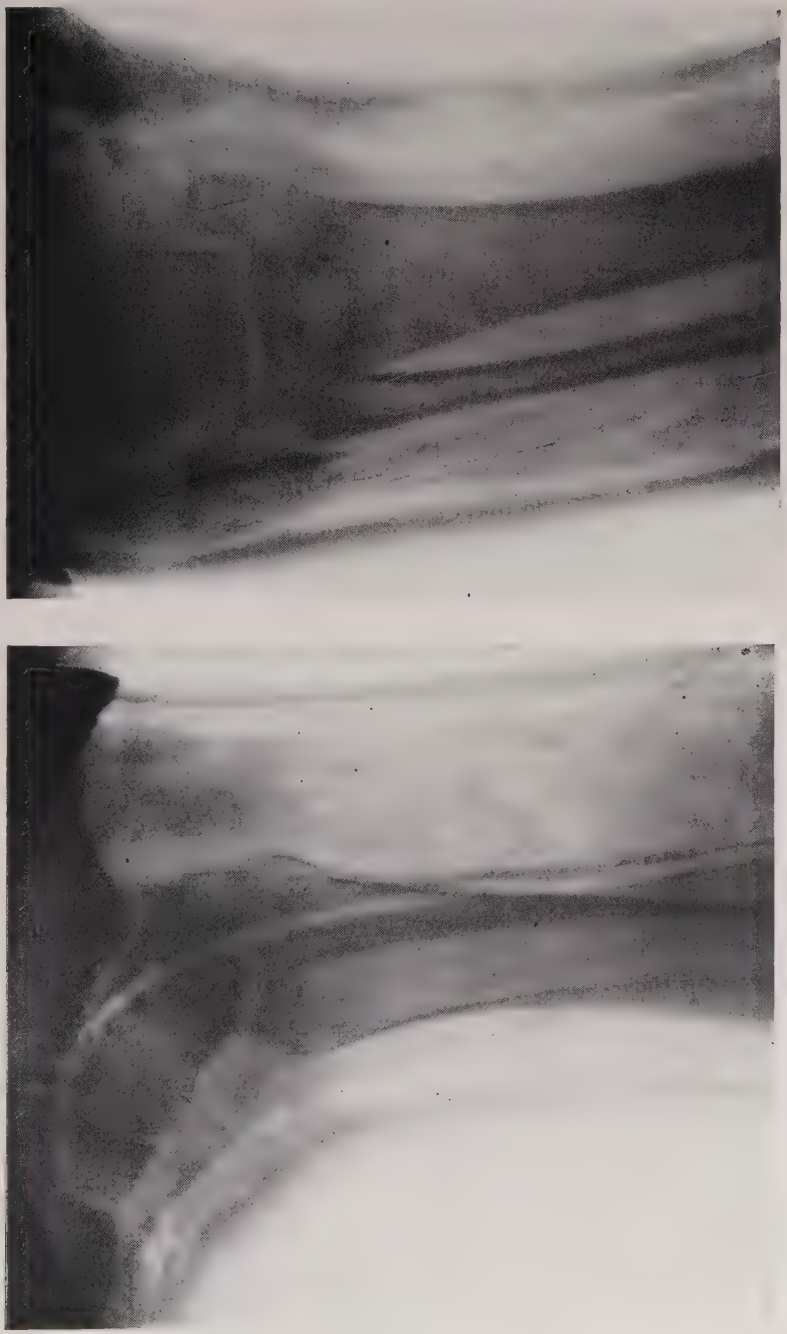
III. DISLOCATION OF THE ANKLE-JOINT

Varieties.—Simple uncomplicated dislocation of the foot without accompanying fracture is a rare injury. Luxation may occur in either the antero-posterior or lateral planes, but owing to the relation which the malleoli bear to the astragalus, it obviously can take place more readily in the former than in the latter direction.

Dislocations in the Lateral Plane.—The inward and outward varieties of dislocation are practically always fracture-dislocations, one of the malleoli being split off and thus permitting displacement. Mention of these injuries has already been made under the heading of Fractures by Adduction and Fractures by Abduction of the Foot. The displacement is usually of an incomplete type and the complete variety, when it does occur, is usually compound (Fig. 916). Occasionally the foot may assume a lateral or mesial position secondary to a primary posterior dislocation.

Dislocation in the Antero-posterior Plane.—Of dislocations in the antero-posterior plane, the posterior variety is the more common, notwithstand-

FIGS. 908 and 909.—Fracture dislocation of ankle, the foot displaced outward and backward. Anterior and lateral appearance before reduction. (Fracture Service, M. G. H.)



FIGS. 910 and 911.—Same case following closed reduction and fixation in plaster of Paris. (Fracture Service, M. G. H.)

ing that from the anatomical viewpoint, with the ankle mortise narrowing behind and the posterior margin of the tibia projecting downward, the anterior type would apparently be easier to produce. This is due to the fact that the weight of the body is scarcely ever brought to bear on the limb in such direction and in sufficient force to produce the anterior dislocation. On the other hand, falls forward on the plantar flexed feet are frequent and the body weight tends to drive the tibia forward on the astragalus, with resulting posterior displacement of the foot. Forward dislocation is resisted by the strong posterior ligament and tendo Achillis, the

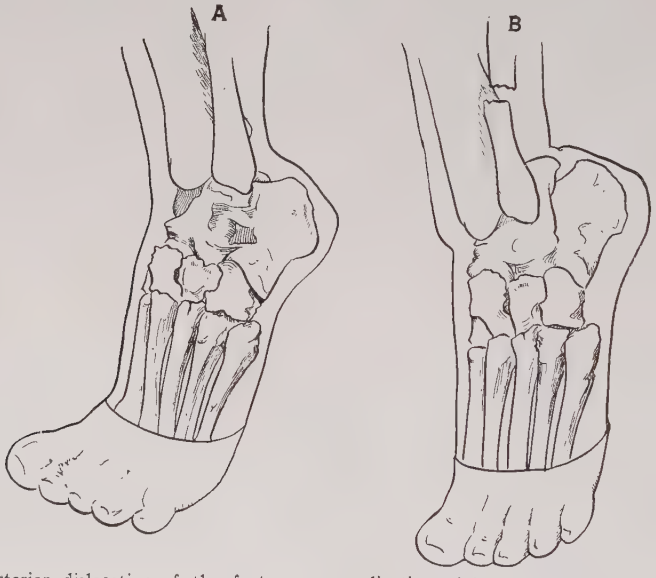


FIG. 912.—Posterior dislocation of the foot as a complication of Pott's fracture. (A) Normal ankle. (B) Foot displaced backward, showing the heel lengthened.

latter being taut during a fall. There are no structures of such strength to resist posterior dislocation.

I. POSTERIOR DISLOCATION

Diagnosis.—There is rupture of both lateral ligaments, and the astragalus lies posterior to the tibia, which now rests on the scaphoid and cuboid. The foot may be rotated as well as displaced backward. When the luxation is complete, the diagnosis is fairly obvious. Partial luxations are more difficult to recognize. There is great swelling of the ankle. The foot appears shortened and the heel is unduly prominent. The lower ends of the tibia and fibula project in front. There is abnormal mobility and extreme tenderness. The displacement is not of a character to imperil the circulation of the foot or its nerve supply (Figs. 912, 913).

Reduction.—Reduction should be performed under anæsthesia, with the knee flexed to a right angle in order to relax the gastrocnemius-soleus muscle group. With the foot in a position of plantar flexion, traction should be applied and the heel drawn forward. When replacement is obtained, the foot should be dorsi-flexed to an angle of 80 degrees to lock the astragalus in position (Fig. 915).

2. ANTERIOR DISLOCATION

Causation and Pathology.—The anterior variety of dislocation may occur as the result of impulsion of the tibia downward and backward

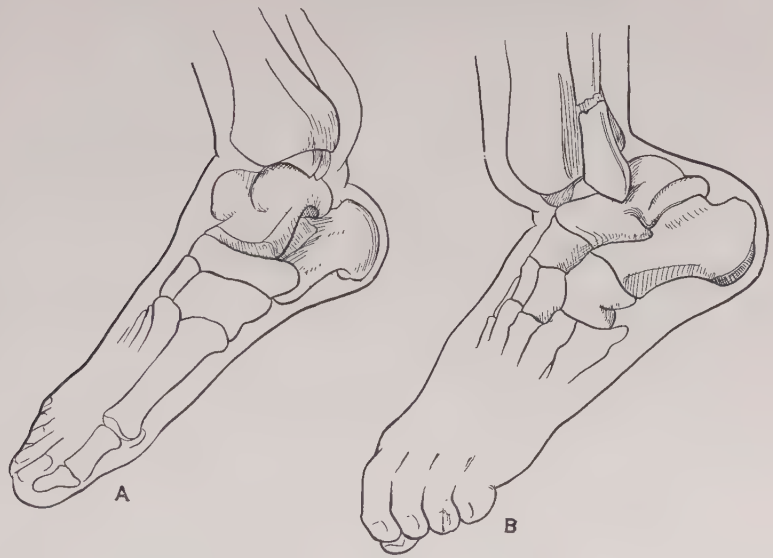


FIG. 913.—Dislocation of the ankle. (A) Anterior dislocation of the foot. (B) Posterior dislocation of the foot associated with Pott's fracture. (After Helferich.)

when the foot is in a position of dorsi-flexion, such as might follow a fall backward and downward when going up-stairs, or it may be produced by violent dorsi-flexion of the ankle. The lateral ligaments are torn and the articular surface of the astragalus lies anterior to the tibia, the latter resting on the os calcis. There is much swelling and there may be interference with the blood and nerve supply, owing to compression of the posterior tibial artery and nerve. There may also be a fracture of the anterior margin of the tibia.

Reduction.—Reduction may be accomplished by manipulation under anæsthesia, additional muscular relaxation being secured by flexing the knee to a right angle. With the foot in a position of extreme dorsi-flexion, traction should be made on the heel and forefoot in a downward and backward direction, while an assistant pushes the tibia forward.

Fixation and After-treatment.— With both types of dislocation, following reduction, it is necessary to fix the foot by the application of a plaster cast extending from the toes to the groin and holding the knee flexed. With the backward dislocation, the foot should be fixed in a position of extreme dorsi-flexion, while with the anterior variety the position of

Fig. 914.—Posterior fracture dislocation of the ankle. (Edinburgh Royal Infirmary.)

slight plantar flexion is the more stable. The plaster should be immediately bivalved to allow room for expansion in case of swelling. Voluntary movements should be instituted at the end of one to two weeks and kept up actively every day. In case of luxation, unaccompanied by fracture, fixation is unnecessary after four weeks. Weight-bearing, with the ankle protected by an adhesive strapping, may be permitted at the end of six weeks.

IV. COMPOUND INJURIES OF THE ANKLE

Occurrence.—Owing to the small amount of soft parts covering the bones at the ankle, compound injuries are not infrequent. They are most commonly fracture-dislocations of the foot, the latter being displaced to one side, while the lower ends of the tibia and fibula are forced out

FIG. 915.—Method of reducing posterior dislocation of the foot. Also useful in fracture of the posterior articular border of the tibia with posterior displacement of the foot.

through the skin. The articular surface is often driven into the ground and covered with earth and badly contaminated (Figs. 916, 917).

Emergency Treatment.—These injuries are always severe and carry a grave prognosis not only for the limb, but for life as well, if severe infection supervenes. Immediately following the accident the wound, with the bones still protruding, should be covered with sterile gauze and the patient rushed to the hospital, with support of the part by pillows or folded garments as the only splinting. Injudicious effort to reduce the displacement on the spot only contaminates the hitherto uninfected portion of the ankle and almost inevitably necessitates the amputation of the foot.

Operative Treatment.—Immediate operative cleansing of the wound should be performed as soon as suitable facilities are obtained. This should include thorough disinfection of the skin, lavage of the protruding bones, and excision of the soiled articular surface and of the thin layer of soft parts overlying the bones. The skin wound should then be excised

FIG. 916.—Inward fracture dislocation of the ankle. This injury was compound. (Edinburgh Royal Infirmary.)

and débridement of the underlying soft parts performed. Then only should the parts be reduced. The wound should be loosely closed with a drain inserted to the ankle-joint, but not entering it. The Carrel-Dakin plan of sterilization is not applicable in these injuries because of the numerous pockets in the joint and the impossibility of bringing the solution into contact with all parts of the surface.

Fixation.— Fixation is best obtained by means of skeletal traction in combination with the Thomas leg splint. A Steinmann pin, passing through or above the os calcis and fastened to a Sinclair skate, affords complete exposure of and access to the wound and at the same time provides fixation and control of the position of the foot (Fig. 919).

Amputation in Case of Sepsis.—If infection supervenes, amputation is usually indicated, and this should be performed promptly, rather than after a period of waiting, which may allow a fatal septicæmia to develop. In

917

918

FIGS. 917 and 918.—Compound fracture dislocation (inward). A good functional result was obtained in this case. Primary healing followed careful débridement. (Fracture Service, M. G. H.)

such cases conservative treatment, even if successful, gives a foot which from the functional standpoint is less good than an artificial one and obtains this result only after many months of treatment and sometimes at the cost of grave risk to life.

FIGS. 919 and 920.—Method of treating compound injuries of the ankle. Roentgenograms of the case shown in figures 917 and 918, following reduction. Note the Hawley pin passing across the os calcis, by means of which extension is applied to maintain correction. (Fracture Service, M. G. H.)

CHAPTER XIX

INJURIES OF THE FOOT

I. FRACTURES OF THE ASTRAGALUS

II. FRACTURES OF THE OS CALCIS

1. Separation of the Epiphysis or Avulsion Fracture of the Posterior Portion of the Os Calcis
2. Fracture of the Sustentaculum Tali
3. Fracture of the Body of the Os Calcis

III. DISLOCATIONS OF THE CALCANEO-ASTRAGALO-SCAPHOID ARTICULATION

1. Incomplete or Subastragaloid Dislocation
2. Total Dislocation of the Astragalus

IV. FRACTURE OF THE BONES OF THE ANTERIOR TARSUS

V. MEDIO-TARSAL DISLOCATIONS

VI. TARSO-METATARSAL DISLOCATIONS

VII. FRACTURE OF THE METATARSAL BONES

VIII. FRACTURE OF THE PHALANGES

IX. FRACTURE OF A SESAMOID OF THE GREAT TOE

X. DISLOCATION OF THE METATARSO-PHALANGEAL ARTICULATIONS

XI. DISLOCATION OF THE PHALANGES

ANATOMICAL CONSIDERATIONS

Structure in Relation to Function.—The structural arrangement of the foot is such as to permit it to perform its twin functions of supporting the body weight and propelling the body forward with the least difficulty. Such use involves a large amount of strain which the foot could not successfully withstand if it were not for its arched design and extreme flexibility. By means of the plantar arches there is provided a spring support to cushion the shock of impact, and also a mechanism for distributing sudden pressure from one part of the foot to other parts so that the load is divided instead of concentrated.

The Arches of the Foot.—The longitudinal arch is in the form of a long, gentle curve beginning at the os calcis and extending forward to the metatarsal bones. It is not, however, a simple curve, but rather a series of curves and arches. Its height is much greater at the inner than at the outer border of the foot, and it is arched in the transverse plane as well. For descriptive purposes the transverse arches are usually subdivided into the posterior arch, which is formed by the tarsal bones (Fig. 922), and the anterior arch, which is formed by the metatarsal bones. In reality the plantar arches form the half of a dome which is made complete when both feet are approximated. The foot is in contact with the ground posteriorly at the heel, externally at its outer border, and mesially at the point corresponding to the head of the first metatarsal. By the elevation of the heads of the middle metatarsal bones from contact with the ground, a space is provided for the transmission, free from pressure, of the vessels and nerves on the inferior surface of the foot.

Skeletal Arrangement.—The bones of the foot are arranged in two main longitudinal systems. The inner one is composed of the astragalus, scaphoid, the three cuneiforms, and the three inner metatarsals and corresponding phalanges. The outer system is formed by the os calcis, cuboid, outer two metatarsals and corresponding phalanges. At their posterior ends they merge to have a common contact with the ground through

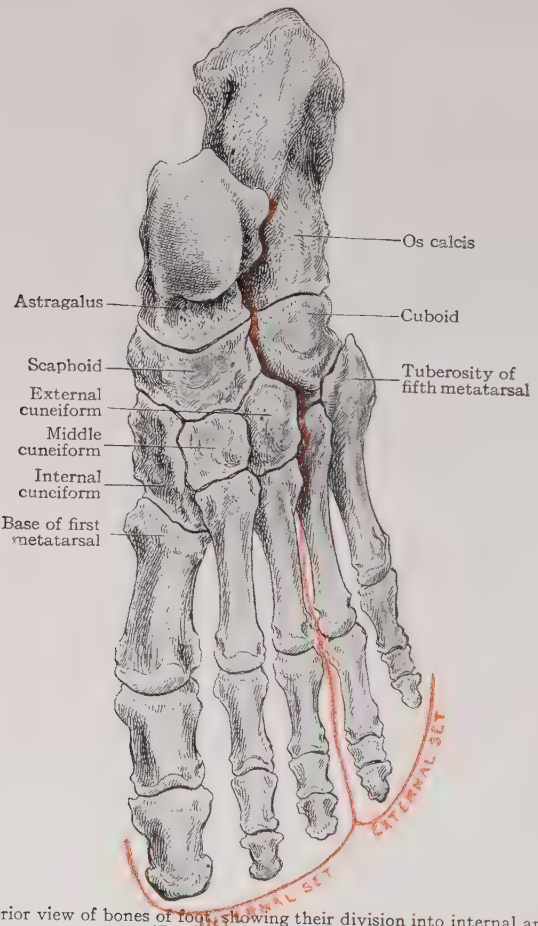


FIG. 921.—Anterior view of bones of foot, showing their division into internal and external sets. (Davis: Applied Anatomy.)

the broad, flat under-surface of the os calcis, upon which the astragalus rests. This constitutes the posterior pillar of the arch. Anteriorly they lie side by side, articulating with each other in the tarsal region and constituting the lateral pillars of the anterior arch. The outer one is in contact with the ground through most of its extent, while the inner one is in contact only through the head of the first metatarsal. The latter, or mesial pillar, however, is obviously the more important in bearing the body weight, because it lies directly in the axis of weight transmission through the tibia. The outer pillar, lying external to the main weight-bearing lines, serves chiefly as the stabilizing arm of the tripod to provide lateral support.

Structure in Relation to Trauma.—The astragalus lies at the summit of the arch and has the function of receiving the body weight from the tibia and of distributing it posteriorly to the os calcis and anteriorly to the inner and the outer pillars. The poste-

rior part of the foot is of heavy and inflexible construction and is intended mainly for bearing weight, whereas the forefoot is made up of a large number of bones of light construction, but protected from trauma by numerous joints, which give flexibility and elasticity. This latter arrangement is better adapted to walking and gives spring to the gait. The difference between these two parts of the foot is important in understanding why they are differently affected by certain types of trauma. Thus, in a fall from a height upon the feet, the force affects chiefly the astragalus and os calcis, either or both of which may be crushed. On the other hand, the forefoot, by reason of its lighter and more elastic construction, usually escapes injury in such accidents, but suffers more severely from direct violence.

The Toes.—The toes are rudimentary structures in relation to the main functions of the foot, although the muscles supplying them are of decided importance in supporting the plantar arch. The great toe assists in propelling the body forward in the act of walking and is of considerable functional importance.

The Calcaneo-astragalo-scaphoid Articulation.—Of the numerous joints the subastragaloid or calcaneo-astragalo-scaphoid articulation is by far the most important, as

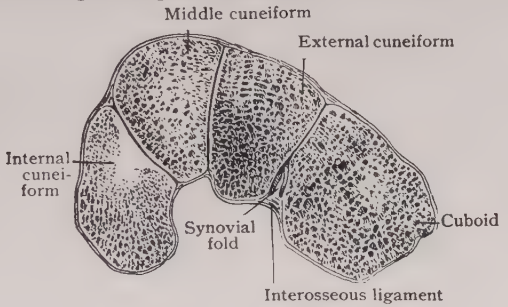


FIG. 922.—Transverse section through the cuneiform bones of the right foot, seen from behind, showing transverse arch. (Piersol: Human Anatomy.)

it is here that the lateral movements of the foot chiefly occur. It consists of two separate articulations (Fig. 923). The posterior one lies between the body of the os calcis and the superimposed body of the astragalus. The facets are dome-shaped with convexity upward. The anterior articulation is formed by the sustentaculum tali, a bony process jutting out from the mesial aspect of the os calcis, and by the inferior surface of the forward-projecting head of the astragalus. The subastragaloid joint is supported by a short interosseous ligament and by the two lateral ligaments of the ankle. The anterior surface of the head of the astragalus articulates with the scaphoid, and this joint communicates with the anterior calcaneo-astragaloid articulation. The inferior surface of the head, while it is supported in part by the sustentaculum, is prevented from pitching downward and inward from the thrust of the body weight by the very important inferior calcaneo-scaphoid ligament. This ligament, which is also known as the "spring ligament" of the foot, extends forward from the sustentaculum tali to the scaphoid under the head of the astragalus and closes the gap which intervenes between these two bones. It is provided with an articular facet on its upper surface where it supports the head of the astragalus.

The Tarsal and Tarso-metatarsal Joints.—The astragalo-scaphoid and calcaneo-cuboid joints lie in the same transverse plane of the foot and may be grouped together under the designation of the mediotarsal joint, although the term has no anatomical basis. These, as well as the anterior tarsal joints, are of little practical importance, as they serve chiefly to give flexibility to the foot, but permit a very slight and indefinite kind of motion. The bases of the metatarsals lie in the same transverse plane, with the exception of the second, which lies at a higher level and is wedged in between the internal and external cuneiforms. This adds considerably to the stability of the joint.

The Joints of the Toes.—The metatarso-phalangeal and interphalangeal articulations are in all respects similar to those of the fingers. They are supported by the

two lateral and the glenoid ligaments. The bones entering into the formation of the metatarso-phalangeal joint of the great toe are quite massive and the joint itself is large. There are two sesamoids interposed between the head of the metatarsal and

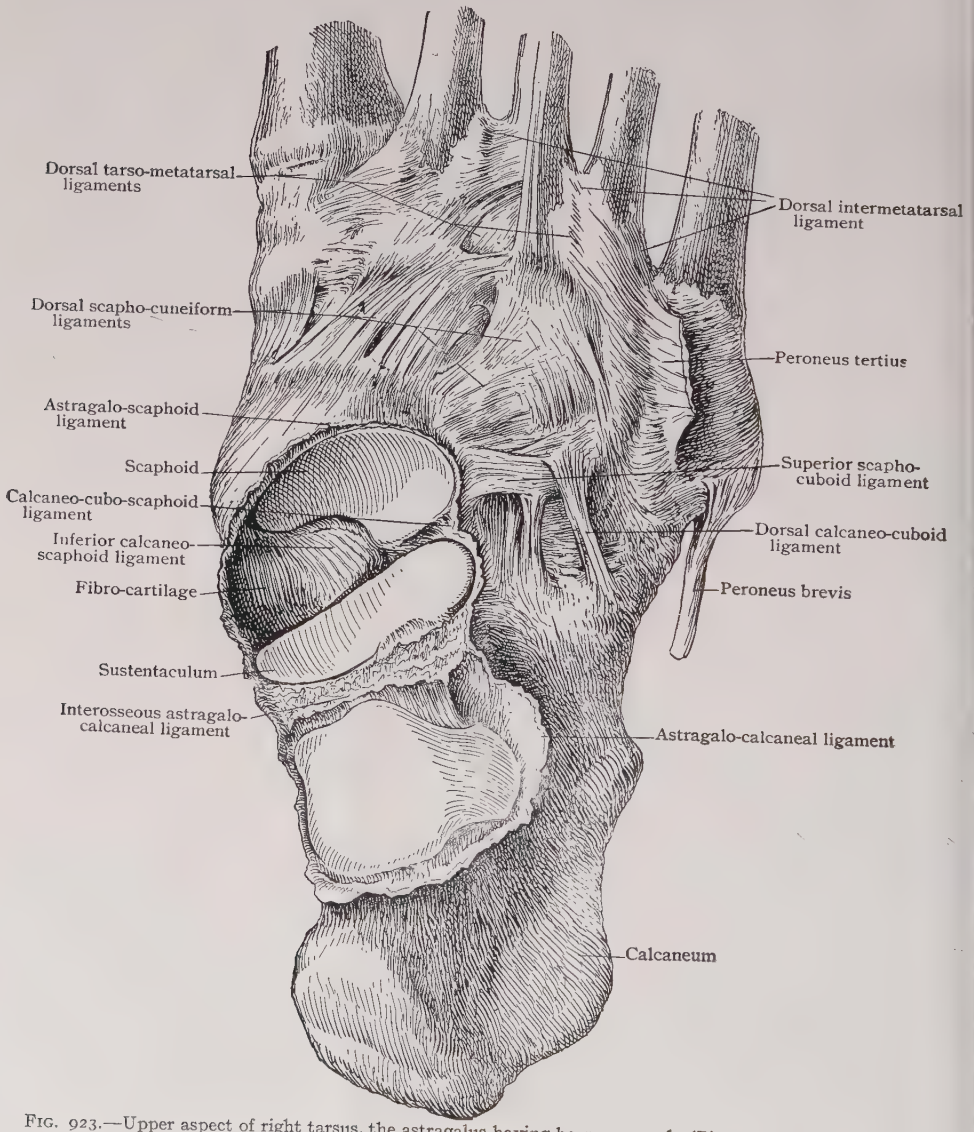


FIG. 923.—Upper aspect of right tarsus, the astragalus having been removed. (Piersol: Human Anatomy.)

the ground (Fig. 924). The mesial one lies in the tendon of the flexor brevis hallucis, while the lateral one lies in the common tendon of the first plantar interosseous and adductor hallucis muscles. The movements of the toes resemble those of the fingers, with the exception that extension is more free.

Movements of the Foot.—Considerable confusion arises from the lack of uniformity in the use of terms to designate the various movements of the foot. Flexion and

extension, or the more descriptive terms, plantar flexion and dorsal flexion, apply to movement of the foot at the tibio-astragaloid joint. The lateral movements of the foot are known as inversion and eversion, or supination and pronation, and take place mainly at the subastragaloid joint. The motion is complex, but the essential feature is inward and outward rotation of the os calcis, the anterior portion of the foot following passively in the movement. Adduction and abduction are usually reserved to describe the movements of the forefoot which occur at the tarsal joints. Scarcely any motion can be demonstrated in this region normally, but under certain conditions deformity may develop and the forefoot be abducted or adducted in relation to the remainder of the foot. Flexion and extension as applied to the toes are easily understandable terms.

Ossification of the Bones of the Foot.—At birth, centres of ossification are present in the calcaneus, astragalus, and cuboid. Centres appear for the external cuneiform in the first year, for the middle cuneiform in the second year, and for the internal cuneiform and the scaphoid during the third and fourth years. A separate epiphysis at the back of the os calcis appears about the eighth year and unites with the body of the bone between the sixteenth and twentieth years.

Each of the metatarsals and phalanges has single epiphyses which appear during the third or fourth year and unite with the shaft at about the age of eighteen. Those

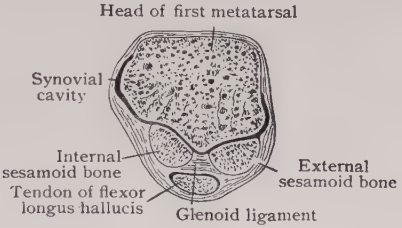


FIG. 924.—Transverse section through head of first metatarsal bone. (Piersol: Human Anatomy.)

of the second, third, fourth, and fifth metatarsals lie at the distal extremity of the bones, while the epiphyses of the first metatarsal and the various phalanges lie at the proximal ends of their respective bones.

Variations in the Bones of the Foot.—Anomalous bones are frequently found in roentgenograms of the foot and may lead to an erroneous diagnosis of fracture if unrecognized. The os trigonum is a small, bony nodule often found at the posterior edge of the superior articular surface of the astragalus (Fig. 930). A sesamoid bone may develop in the tendon of the tibialis posticus muscle, in close proximity to the scaphoid, the os tibiale externum (Fig. 931). Sesamoids are quite frequently found at the outer border of the cuboid in the tendon of the peroneus longus muscle and are known as the os vesalianum and os peroneum. The calcaneum secundum is a small bone occasionally found lying below the astragalus between the calcaneum and the cuboid.

Comparative Importance of Ligamentous and Muscular Support.—The muscles of the foot, in addition to their usual function of producing active movements at the various joints, perform the very important duty of supporting and maintaining the height of the plantar arches. It must always be borne in mind that the strength of the arches of the foot is not derived from the configuration of the bones which enter into their formation, but is dependent upon the ligaments and muscles that hold the bones together. Of these two supporting structures, the muscles are by far the more important because they are actively contractile, while the ligaments are not. The latter are able temporarily to withstand a very strong force, but yield before moderate but long continued strain unless relieved by muscular help.

Supporting Function of the Muscles.—Both the intrinsic and extrinsic muscle groups contribute to the support of the arches. The intrinsic muscles, by bridging the longitudinal arch in a bow-string manner, serve to unite the two extremities and draw them together. The extrinsic muscles provide support in different ways according to their arrangement (Fig. 933). The tibialis anticus muscle, through its insertion at the base of the first metatarsal, exerts a direct elevating pull. The tendon of the peroneus longus

muscle runs obliquely forward on the plantar surface from the cuboid to the inferior surface of the base of the first metatarsal, and thus exerts a bowstring action, supporting both longitudinal and transverse arches. The tibialis posticus muscle functions

925

926

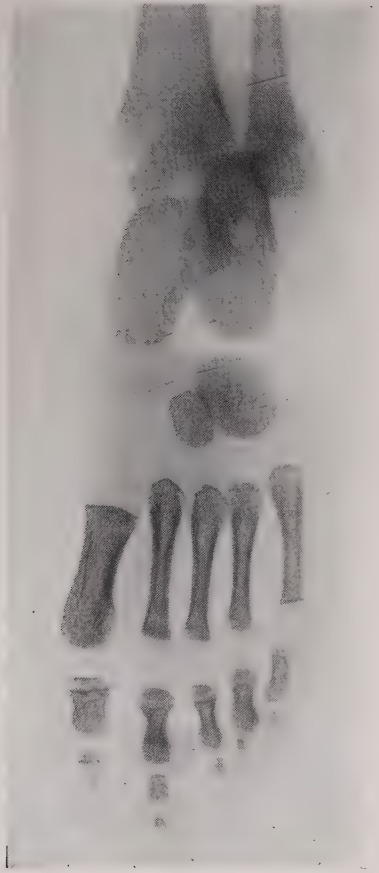
927

FIGS. 925, 926 and 927.—Ossification of the bones of the foot. Lateral roentgenograms. (925) Age of two years. (926) Age of seven years, three months. (927) Age of eleven years.

in a nearly similar manner, only from the opposite side of the foot. The flexor longus hallucis muscle has a very important supporting function, which is exerted on the sustentaculum tali of the os calcis, a key structure of the arch. As it runs forward to the great toe from behind the internal malleolus, it passes down and under this bony process, which serves as a pulley to change the direction of the tendon. In the standing position, with flexion of the great toe prevented by contact with the ground, contraction of this muscle lifts the sustentaculum tali and thus supports the arch. A less definite but similar supporting function may be traced out for nearly all the muscles of the foot.

FOOT-STRAIN, FLAT-FOOT, PRONATED FOOT

Relation of Traumatic and Functional Flat-foot.—An understanding of the various functional disturbances of the foot is important for the proper treatment of fractures in this region. The latter are chiefly important as they affect the weight-bearing mechanism, either by actual displacement of the bones and malunion, or by the combined



928

929

FIGS. 928 and 929.—Ossification of the bones of the foot. Antero-posterior roentgenograms. (928) Age of two years. (929) Age of four years.

effects on the soft parts of the original trauma and subsequent fixation. Such injuries are frequently followed by long periods of disability, and the symptoms of which the patients complain are those of flat-foot or foot-strain. The convalescent treatment of fractures of the foot is essentially similar to the treatment of the ordinary case of foot-strain, and from the standpoint of prevention as well as that of treatment, a knowledge of this condition is essential.

Unimportance of the Height of the Arch.—It should first be emphasized that the height of the arch is of little importance in determining the presence or absence of a condition of strain. The greatest variation exists normally in the height of the arch in different individuals. A person with a very high arched foot may develop symptoms with comparatively little flattening, while another may have a perfectly strong, painless

foot with the arch so low as to barely escape contact with the ground. The test in all cases should be functional rather than anatomical.

Normal Muscle Balance.—The causes of foot-strain are many, but all produce their effect by weakening the normal muscular supports of the arch, so that an excessive burden is thrown upon the ligaments, which consequently become strained. The chief supporting muscles of the arch are those which cause the movement of supination. Supination raises the arch, while pronation tends to flatten it. In a general way, therefore, the supinating muscles may be regarded as the benevolent group and the pronators as the malevolent or destructive group. Preservation of normal foot balance is dependent upon the supinating muscles being stronger than the pronating muscles. It has been shown by Osgood[1] that when the strength of these muscles is measured, the normal ratio is

FIG. 930.—Roentgenogram of os trigonum.

found to be as 5:4 in favor of the supinators (Fig. 934). In weak feet the balance is even, and in conditions of foot-strain the ratio is reversed.

Pathology.—When the normal foot-balance is disturbed, the ligaments cannot long withstand the strain. The os calcis rotates outward and the head of the astragalus bears heavily on the inferior calcaneo-scaphoid ligament, which gives way, allowing the head of the bone to pitch downward. The foot pronates and the internal malleolus becomes abnormally prominent. This movement is resisted by the internal lateral ligament of the ankle, which also becomes strained. At a later stage, due to the abnormal thrust of the astragalus, the forefoot is pushed over to the outer side (abducted), and the inner border of the foot becomes convex.

Diagnosis.—Early fatigue and pain referred to the mesial side of the foot and radiating up the leg are the first symptoms noted. Examination at this stage shows no restriction of the movements of the foot, but tenderness on pressure over the inferior calcaneo-scaphoid and internal lateral ligaments. At a later stage there is prominence of the internal malleolus and of the head of the astragalus and, when viewed from behind, the os calcis is seen to be tilted outward. At a still later period the foot loses its flexibility and the arch cannot be restored by inversion of the foot. This is the stage of rigid flat-foot.

[1] R. B. Osgood, *Amer. Journ. Orth. Surg.*, January, 1908, p. 298.

Causes of Foot-strain.—The causes of foot-strain, as usually given, are multitudinous. They may be of a general nature, such as a wasting illness, change from a sitting to a standing occupation, and other similar factors which may result either in over-use and fatigue of the muscles or in weakening of the muscles and loss of normal tone. Of far greater importance, however, as direct and specific causes are the effects of improper shoeing, imperfect poise of the body, and faulty gait.

Improper Shoes.—Improper shoes cramp the feet and prevent the normal expansion of the arch when weight is borne. Most shoes are too small for the feet they contain

FIG. 931.—Roentgenogram showing the os tibiale externum. This is a sesamoid which lies in the tendon of the tibialis posticus muscle.

or else deform the feet by improper shape. High heels transfer the entire thrust of the body weight to the forefoot and lead to relaxation of the anterior arch and weakening of the general supportive mechanism.

Faulty Posture.—Imperfect poise is a very important cause through its effect in changing the normal lines of weight-transmission to the foot. In the erect posture the weight of the body reaches the apex of the arch with a perpendicular thrust which permits its even distribution between the heel and forefoot. The work is evenly divided among the various muscles, and balance is easily maintained. With faulty posture this is not the case; the weight falls more heavily on the heels, and certain of the muscles are relaxed, while others carry a heavier burden than they should. This inevitably leads to weakening of the foot, disturbance of muscle balance, and ultimate strain.

Faulty Gait.—By faulty gait is chiefly meant the common habit of "toeing out" when walking. This leads to pronation of the foot, as the line of weight transmission falls too far to the inner side of the axis of the foot. Also in this position no support is obtained from the short, external rotator muscles of the hip, which, when the foot is placed rightly on the ground, exert a distinct supinating effect. The correct position of the foot when walking is with the toes pointed directly forward or even a little inward.

Treatment—Immediate Measures.—In the treatment of foot-strain, one of the first steps should be the replacement of improper footwear by shoes of good line and ample size. Rest and relaxation of the strained structures may be obtained by different

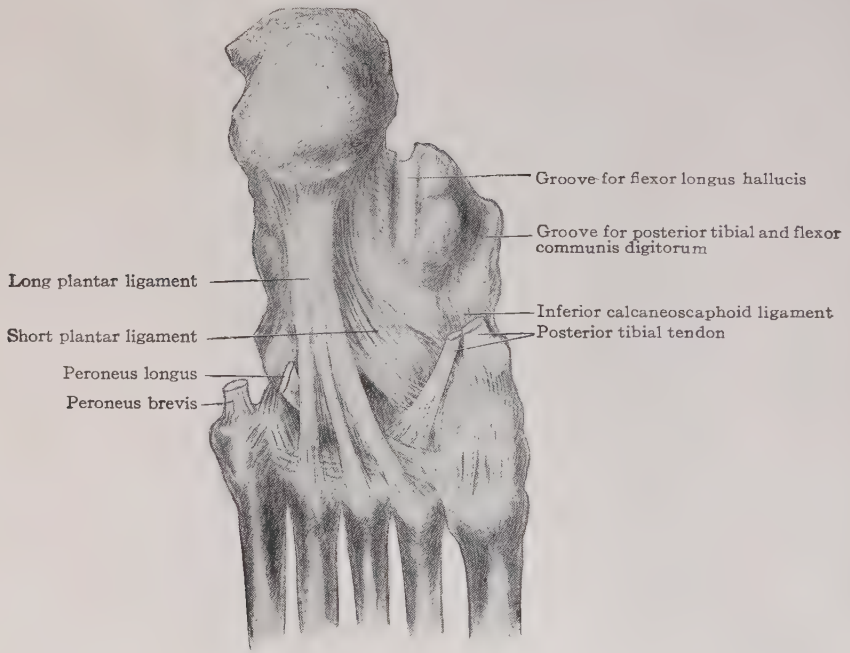


FIG. 932.—Ligaments and tendons on the plantar surface of the foot. (Davis: Applied Anatomy.)

types of braces or dressings. The longitudinal arch may be padded with felt and a stirrup strapping of adhesive plaster applied which holds the foot well supinated (Fig. 935). The anterior arch may be similarly supported by an encircling band of adhesive plaster with felt pads placed beneath the metatarsals. More permanent support may be obtained by the use of Thomas heels (Fig. 936), the inner border being raised six mm. and extended forward 1.25 to 2 cm. Painful pressure on the metatarsal heads may be relieved by nailing a strip of leather one inch wide and one-quarter inch thick obliquely across the sole just behind the tender area (Fig. 937). In mild cases sufficient support for the longitudinal arch may be obtained by the use of a figure-of-eight leather ankle strap (Fig. 938), or for the anterior arch by a laced leather foot-cuff (Fig. 939).

Arch Supports.—The making of foot-plates is more difficult, but they are often necessary following fractures of the foot, particularly those involving the os calcis. They should be made in every instance from plaster impressions of the patient's feet and with regard to the special indications of the individual case (Fig. 941). When plates have been worn for some time, the tendency is for the patient to become dependent upon them. The physician's duty does not, therefore, stop with the fitting of the plates, but only after the treatment has been carried far enough so that the patient may dispense with them.

Exercise Treatment.—After a sufficient period of rest, as shown by the subsidence of painful symptoms, exercise treatment should be begun. The patient should be instructed in the elements of correct poise, how to hold the body in the erect posture,

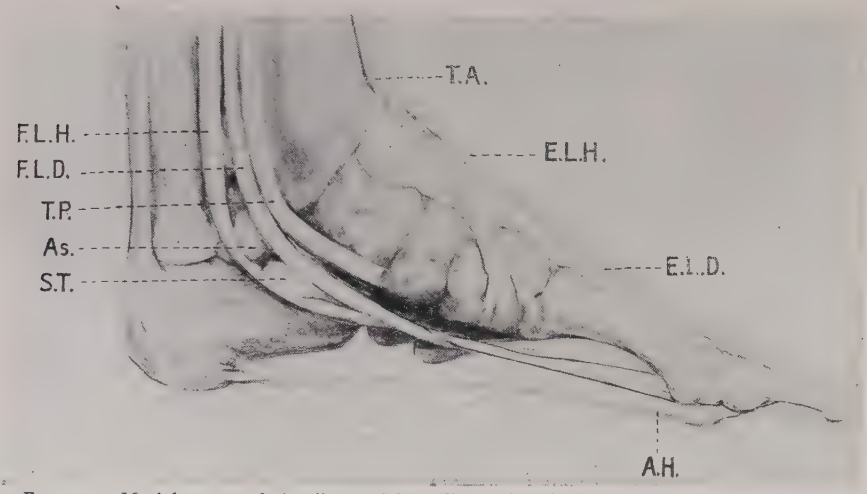


FIG. 933.—Mesial aspect of the dissected foot, illustrating the functions of the various muscles in supporting the arch. (A.H.) Adductor hallucis. (E.L.D.) Extensor longus digitorum. (E.L.H.) Extensor longus hallucis. (T.A.) Tibialis anticus. (F.L.H.) Flexor longus hallucis. (F.L.D.) Flexor longus digitorum. (T.P.) Tibialis posticus. (As.) Astragalus. (S.T.) Sustentaculum tali.

with chin in, chest elevated, abdomen contracted, and the back flat. Emphasis should be placed on the correction of faulty gait by toeing straight ahead or slightly inward. Special exercises to strengthen the supinator muscles of the foot should be given and

FIG. 934.—Method of testing the muscle balance of the foot.

the patient taught to use them when standing or walking. Picking up marbles with the toes is a valuable exercise to strengthen the toe flexors, which, as has been shown, are important supporting muscles.

Treatment of Rigid Flat-foot.—Treatment of rigid flat-foot constitutes a problem in itself. If the rigidity is due to muscle spasm, tenotomy of the affected muscles may be indicated. If the rigidity is only partial, the foot may be manipulated under an anæsthetic and the arch restored by forcible inversion of the foot, followed by fixation in plaster for two to four weeks. If the rigidity is so complete that manipulation is of no avail, open operation with osteotomy is indicated to restore the normal weight-bearing lines.

FIG. 935.—Method of supporting the arch by a stirrup strapping of adhesive plaster holding the foot in the position of inversion.

FIG. 936.—Thomas heel. Note that it is ¼ inch higher on the inner side than on the outer side, and that the inner border is extended forward ½ to ¾ inches.

FIG. 937.—Metatarsal bar or anterior heel. This is a strip of leather ¼ inch thick which is inserted between the layers in the sole of the shoe and extends across the foot just behind the heads of the metatarsals.

FIG. 938.—Figure-of-eight leather ankle straps. These are used in mild cases of foot-strain.

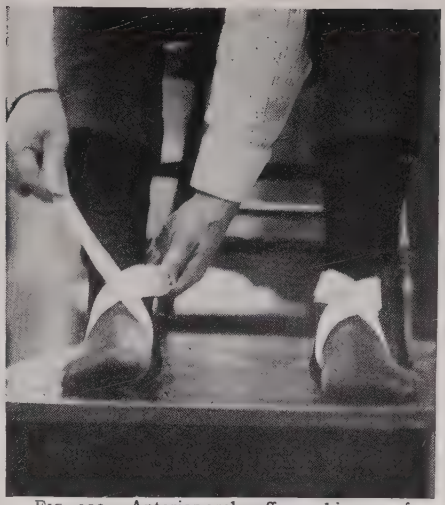


FIG. 939.—Anterior arch cuffs, used in case of spreading of the anterior arch.

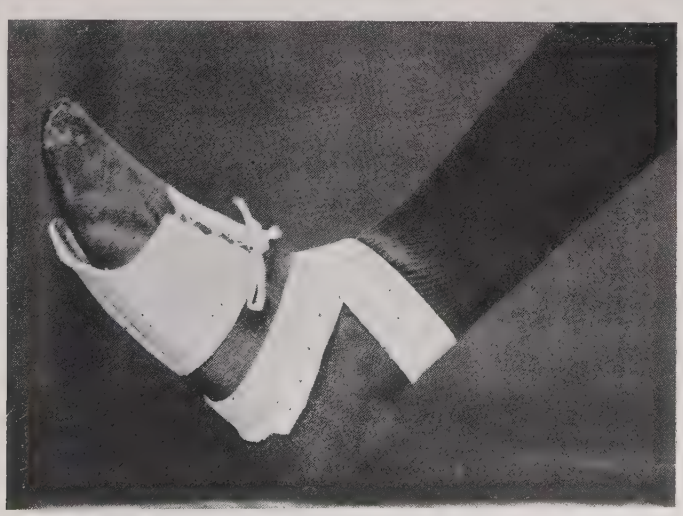


FIG. 940.—Figure-of-eight ankle strap combined with anterior arch cuff, the latter containing a thick pad of felt which elevates the metatarsal heads and supports the anterior arch.

941

942

943

944

FIGS. 941, 942, 943 and 944.—The making of arch supports. (941) Plaster cream is prepared and poured into an open pan. (942) The foot is placed in the plaster, in the corrected position. (943) When the plaster has hardened, the foot is removed. (944) The plaster mould completed. From this impression, a positive mould is made with plaster, and this is shaved down and the outline of the plate marked upon it. With this model as a guide, it is not difficult to secure an accurately fitting plate.

FRACTURES AND DISLOCATIONS OF THE FOOT

I. FRACTURE OF THE ASTRAGALUS

Types of Fracture.—This injury almost always occurs as the result of a fall from a height upon the feet and is not infrequently associated with fracture of the os calcis or of the lower end of the fibula. Two distinct types of fracture are recognized, the first a compression fracture involving the body of the bone, and the second a fracture through the neck.

Fracture of the Body.—The former is accompanied by general comminution and impaction which is practically impossible to correct. Operative intervention may be indicated in such cases but is best undertaken as a

late procedure when the amount of residual disability and its specific cause may be recognized and corrected. The immediate treatment is plaster fixation, with short, daily periods of active mobilization and massage of the foot, beginning almost at once.

Fracture of the Neck.—Fracture of the neck of the astragalus with displacement may be corrected by inverting the foot, moulding the arch, and fixing the ankle in the position of right-angle flexion. Immobilization is secured by the application of a plaster of Paris boot, which should be left on for a period of six weeks. Active movements are begun at the end of two weeks. In case limited and painful movement at the subastragaloid joint results, an operation to remove the cartilaginous surfaces and ankylose the joint is indicated.

II. FRACTURES OF THE OS CALCIS

Injuries of the os calcis may take any one of three forms, and these will be considered separately.

1. SEPARATION OF THE EPIPHYSIS OR AVULSION FRACTURE OF THE POSTERIOR PORTION OF THE OS CALCIS

Causation and Displacement.—This injury is quite rare and occurs usually as the result of a fall upon the ball of the foot. The force is resisted by the contraction of the tendo Achillis, with the result that the portion of bone to which the tendon is attached, or the epiphysis, in case it is not yet united, is torn away (Fig. 948). Muscular retraction occurs if the separation is complete and may result in considerable displacement of the fragments.

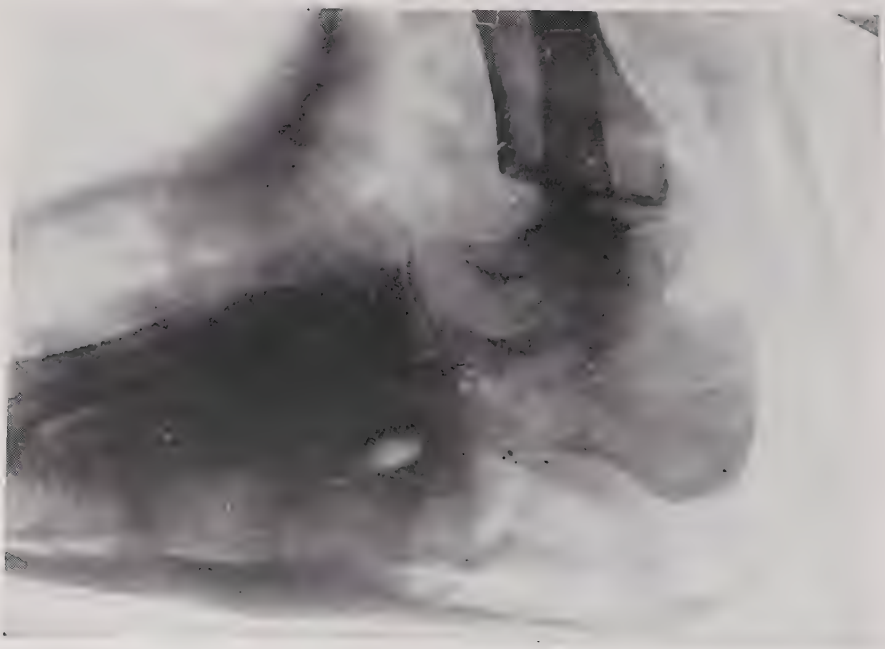
Treatment.—In the presence of displacement, open reduction and fixation of the fragments by the insertion of a bone peg or suture with kangaroo tendon is indicated. Fixation is obtained by the application of a plaster cast extending from the toes to the groin, with the knee flexed and the foot in the position of plantar flexion, in order to relax the tendo Achillis. When the fracture is not accompanied by displacement, immobilization alone is sufficient.

The cast may be split, and massage and supported movement of the ankle-joint begun at the end of four weeks. At the end of six weeks the cast is removed and weight-bearing permitted with a raised heel, which removes tension from the tendon and prevents strain at the fracture line. After a week or two the heel should be gradually lowered and exercises given to stretch out the tendon and regain the full range of ankle motion.

2. FRACTURE OF THE SUSTENTACULUM TALI

Occurrence.—This fracture is also quite rare and usually results either from forced inversion of the foot or from a fall upon the foot with the ankle in the dorsiflexed position. The fracture line runs through the

945



946

FIGS. 945 and 946. —Compression fracture of the upper articular surface of the astragalus. (945) Original deformity. Note the bony block which interferes with dorsal flexion of the foot. (946) Same case following open interposition. The bony block has been removed, also the anterior articular border of the tibia, and the foot has been immobilized in the dorsally flexed position. The result was good function with 20–25 degrees range of motion.

articular facet of the sustentaculum or through the base of the process. Usually only slight displacement results (Fig. 949).

Diagnosis.—There is marked pain and swelling and the lateral movements of the foot are painful and limited. There is marked tenderness on pressure over the mesial and plantar aspects of the foot near the front of

FIG. 947.—Lateral view of foot, showing the epiphysis of the os calcis. Age of eleven years.

the os calcis. The diagnosis, however, depends chiefly upon the evidence obtained from the roentgenogram.

Prognosis.—The real significance of this fracture lies in the fact that there is always accompanying injury of the inferior calcaneo-scaphoid ligament, the spring ligament of the foot, which is attached at the base of the sustentaculum. The head of the astragalus is supported partly by this ligament and partly by the sustentaculum. Injury to these structures is, therefore, likely to result in downward tilting of the astragalus and flat-foot.

Reduction.—The treatment consists in restoration of the arch by moulding the foot under general anæsthesia, followed by the application of a plaster of Paris boot. The foot should be strongly inverted and held in the position of right-angle flexion, with the arches carefully supported.

After-treatment.—The cast should be worn for six weeks, but massage and active movement may be begun at the end of two to three weeks, the cast being split for the purpose. Weight-bearing may be begun at the end

FIG. 948.—Avulsion fracture of the posterior portion of the os calcis. This requires operative replacement. (Fracture Service, M. G. H.)

of six weeks, but it is absolutely essential that support for the arch of the foot be provided. This necessitates the careful fitting of a steel arch support, made from a plaster impression of the patient's foot. Failure to restore and later to protect the plantar arch in this type of injury will almost invariably be followed by serious and persistent disability.

3. FRACTURE OF THE BODY OF THE OS CALCIS

Occurrence.—Fracture of the body of the os calcis is a very frequent injury. It is almost invariably the result of a fall from a height upon the feet, the bone being crushed by the impact of the body weight.

Pathology.—The injury varies greatly in severity, depending chiefly upon the height of the fall. The bone may be only cracked through, without displacement, or there may be severe comminution, the body of the bone being reduced to a mass of fragments. Impaction of greater or lesser extent is the rule. Not infrequently both os calces are fractured together or there may be an associated fracture of the astragalus. Occasionally, in the very severe cases, the fracture is compound. In falls from a great height the fracture is commonly accompanied by other grave injuries, such as fracture of the skull, pelvis, or hip.

FIG. 949.—Fracture of the sustentaculum tali without displacement. (Fracture Service, M. G. H.)

Displacement.—The os calcis is deformed by the injury in a fairly characteristic way. There is usually a longitudinal fracture line through the body of the bone with one or several perpendicular fissures running down through the inferior surface. The upper portion of the bone is impacted into the lower, with flattening of the posterior pillar of the plantar arch, the projecting posterior tuberosity being driven upward.

Owing to the fact that the line of transmission of the body weight does not normally fall through the centre of the os calcis, but rather to its mesial side, the inferior and lateral portions of the os calcis are uniformly

FIG. 950.—Comminuted fracture of the body of the os calcis.

displaced upward and outward, causing a bulge under the external malleolus (Figs. 950 to 954).

Diagnosis.—The history of an injury to the heel following a fall from a height should immediately suggest the nature of the injury. On examination, there is swelling of the heel and marked tenderness on pressure. Movements at the ankle-joint proper, that is, dorsal and plantar flexion,

are free and only moderately painful, while movements of the foot in the lateral plane at the subastragaloid joint are extremely painful and greatly restricted. Deformity of the bone is often demonstrable by palpation, particularly the outward bulging beneath the external malleolus. Crepitus is often present, due to the presence of small, loose fragments of bone. In cases with extensive comminution the heel is soft and mushy, and abnormal mobility may be demonstrated.

Roentgen Examination.—Roentgenological examination is always necessary and in addition to the usual lateral and antero-posterior views, an

FIG. 951.—End result of old comminuted fracture of the os calcis with malunion. Note the distortion of the subastragaloid joint. This foot was extremely painful and disabling. (Fracture Service, M. G. H.)

exposure should be made obliquely downward through the posterior part of the heel, with the foot dorsally flexed as much as possible (Fig. 952). While it is possible from the clinical examination alone in the majority of cases to make the diagnosis of fracture of the os calcis, an accurate idea of the injury, extent of displacement, degree of comminution, and association with other fractures can be obtained only from study of the roentgenograms.

Prognosis.—The treatment of a case of fracture of the body of the os calcis should never be undertaken lightly. It is one of the most serious of the injuries of the lower leg and has more frequently resulted in permanent disability than almost any other fracture. This is due to the difficulty and often the impossibility of securing replacement of the fragments in their original position and to the important function of the

os calcis in forming the posterior pillar of the plantar arch. The special causes of disability may be considered under four general headings.

CAUSES OF DISABILITY

1. Traumatic Flat-foot.—This is the result of the uncorrected upward displacement of the posterior portion of the os calcis. Union occurs with the posterior portion of the arch flattened, and the entire spring mechanism

FIG. 952.—Fracture of the os calcis. The roentgenogram was made by directing the rays vertically downward through the heel. Note that the posterior fragment is displaced outward to the right. (Fracture Service, M. G. H.)

of the foot is destroyed. When use of the foot is begun, strain of the ligamentous structures follows (Fig. 953).

2. Lateral Displacement of the Heel.—Failure to correct the outward displacement of the heel seriously disturbs the mechanics of the foot. The line of transmission of the body weight falls too far to the mesial side of the posterior pillar of the arch, with the result that the foot is forced over into the pronated position and resulting strain is inevitable (Fig. 952).

3. Limitation of the Lateral Movements of the Foot.—The lateral movements of the foot serve a very important purpose when walking on an uneven surface, in allowing the foot to conform to the irregularities of the ground. Fracture of the os calcis not infrequently involves the sub-

astragaloid joint, causing distortion of the articular facet and the formation of adhesions (Fig. 951). Unfortunately, complete ankylosis rarely results and instead there is limitation of movement and pain on use. The same symptoms may result from the development of exuberant callus on

FIG. 953.—Comminuted fracture of the os calcis with marked flattening of the arch.

the upper outer surface of the os calcis. This impinges against the external malleolus, thus causing limitation, irritation at the point of contact, and pain on use.

4. **Spur Formation on the Under Surface of the Os Calcis.**—This may result from the extrusion of a small fragment from the main body of the bone at the moment of fracture or may be due simply to an irregular callus formation at the fracture line. Contact of the heel with the ground may cause excessive pressure upon this point and produce pain.

If good results are to be obtained in fractures of the os calcis, the treatment must be directed particularly toward the avoidance of these four main causes of disability.

Reduction.—Reduction under general anæsthesia should be performed in all cases in which displacement exists. Impaction must be broken up,

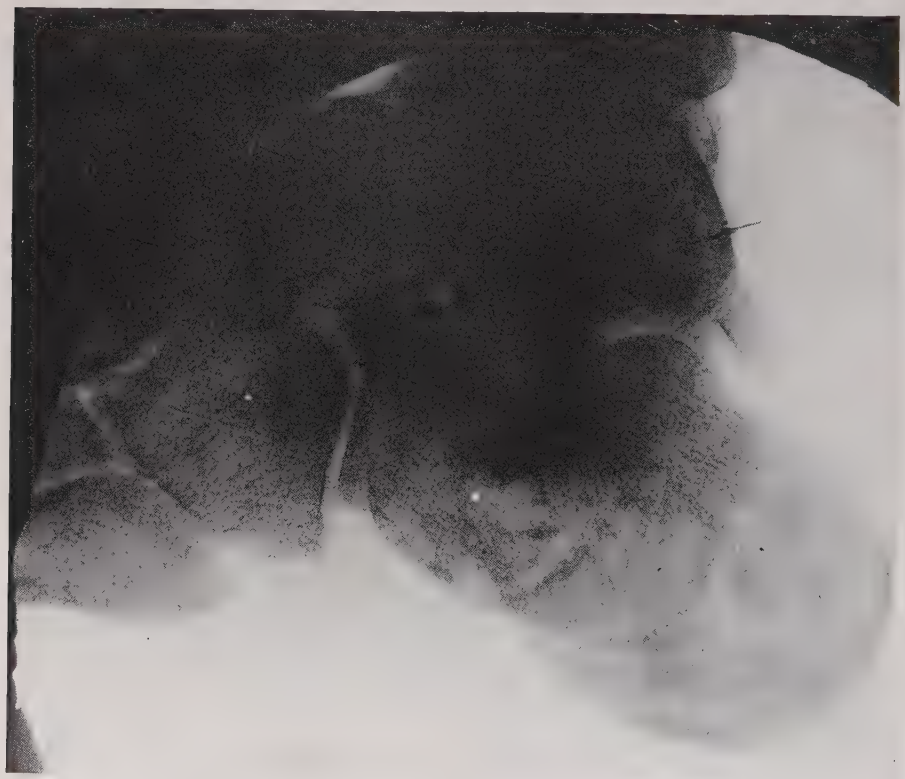


FIG. 954.—Same fracture as shown in Fig. 953, after reduction. Subcutaneous tenotomy of the tendo Achillis was performed and the posterior portion of the os calcis pulled downward by passing a pin across its top. An excellent functional result was obtained.

lateral displacement corrected, and the downward curve of the posterior pillar of the arch restored. This is much easier said than done and the method to be used will depend chiefly upon the problem presented by the individual case.

Obstacles to Reduction.—The two chief obstacles to reduction are the deforming influence of the gastrocnemius-soleus muscle group exerted by the tendo Achillis on the posterior part of the calcaneus and firm impaction of the fragments. To obviate the first, it is necessary to plantar-flex the foot and also to flex the knee. The second often constitutes a serious difficulty, as it is impossible to grasp the fragments firmly enough to utilize the strength of the hands. In this case a Thomas wrench may

be applied to the heel and worked back and forth until the fragments are loosened.

The Mallet Method.—If there is marked displacement of the inferior and posterior portion of the bone to the outer side, a mallet may be used as suggested by Cotton.[2] A sand bag is placed under the mesial surface of the heel. The outer surface is covered with a cotton pad and pounded several times. This breaks up the impaction and drives the displaced portion of the bone back into its normal position.

When the fracture is much comminuted without impaction, it is usually easy to mould the fragments back into some semblance of their former shape by manual force alone. Fixation should be with the foot in plantar-flexion in order to relax the tendo Achillis.

Skeletal Traction Method.—When upward displacement of the posterior portion of the bone is the predominating feature and cannot be corrected because of impaction, it may be necessary to pass a metal pin through small skin incisions over the top of the os calcis. By this means a direct grasp of the displaced fragment is obtained and it may be pulled downward into position and the pin removed. If the deformity recurs after correction with the foot in plantar-flexion, it will be necessary to perform a subcutaneous tenotomy of the tendo Achillis. In adults, this operation is likely to result in permanent weakening of the triceps suræ and should never be used except as a last resort.

Open Reduction.—Open reduction is rarely indicated and is attended by considerable risk in fresh cases because of the superficial position of the bones and the damaged condition of the subcutaneous tissue. Infection occurs very readily under such conditions.

Fixation.—Fixation is obtained by the application of a plaster cast extending from the toes to the groin. Mention has already been made of the importance of plantar-flexion of the foot and flexion of the knee in maintaining the position of the fragments. Although plantar-flexion is not the best functional position for immobilization of the foot, it should be remembered that there is no injury to the tibio-astragaloid joint where this movement occurs, and that there is, therefore, no danger of ankylosis in this position. The foot should also be held in the position of inversion, and the arch should be well supported by moulding the plaster.

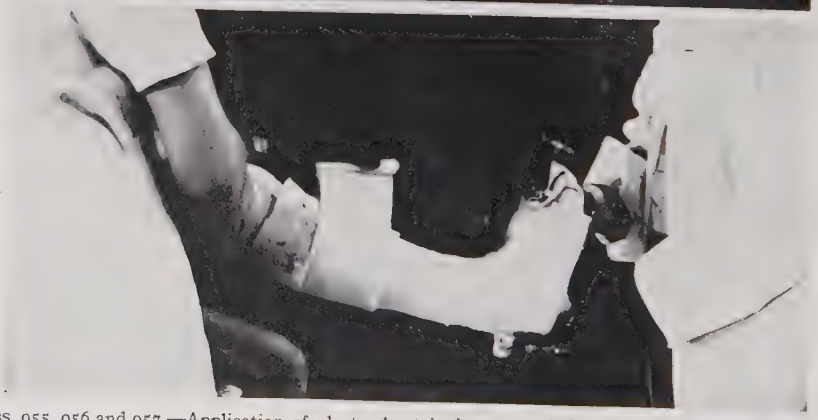
After-treatment.—It is necessary to continue the use of the plaster cast for a period of about six weeks, although it may be possible to cut away the portion extending above the knee at an earlier date. The cast should be bivalved at the end of two to four weeks and massage and active movement begun. Physio-therapeutic treatment should be carried out daily and for gradually increasing periods. At the end of six weeks the cast is

[2] F. J. Cotton, *Annals of Surg.*, Vol. 64, p. 481, 1916.

955

956

957



FIGS. 955, 956 and 957.—Application of plaster boot in fractures of the foot. (955) Showing method of holding the foot inverted and the arch supported with the thumb of the left hand. (956) Application of stocking material and felt pads to cushion the edges of the cast. (957) Cotton applied for padding.

958

959

FIGS. 958 and 959.—Application of plaster boot in fractures of the foot. (958) Application of the plaster. (959) Cast completed; the foot is being held in the corrected position while the plaster is hardening.

removed altogether and a flannel or woven elastic bandage applied. Weight-bearing should not be permitted before the end of eight weeks and then only with a steel arch support made from a plaster impression of the foot. The use of this brace should be continued for three or four months.

Treatment of Malunited Fractures.—Much may be done for the improvement of patients who are suffering from the disabling effects of an old malunited fracture of the os calcis. Conservative treatment consists in the correction of faulty mechanics of the foot by the use of tilted heels,

ankle straps, arch supports, and exercises (see p. 743). When these measures are unsuccessful and there is obvious bony deformity to be corrected, operative intervention is indicated. Upward displacement of the tuberosity of the os calcis may be remedied by oblique osteotomy at the base of the process and correction of the deformity. If a bony mass is present on the lateral surface of the os calcis which impinges against the external malleolus, this, with a generous portion of the underlying base, should be removed. Painful and limited lateral movements of the foot, due to derangement of the calcaneo-astragaloid joint, may necessitate an operation to excise the articular surfaces and secure solid bony ankylosis. Lastly, spurs or loose fragments of bone on the plantar surface of the heel, causing points of painful pressure, may be removed.

Success depends upon careful appraisal of the relative importance of these several factors in each individual case, and proper selection of the operative procedure which best fits the problem.

III. DISLOCATION AT THE CALCANEO-ASTRAGALO-SCAPHOID ARTICULATION

Mechanism of Dislocation.—These injuries occur almost always as the result of a fall upon the inverted or everted foot when the ankle is at the same time plantar-flexed. The force is received on the ball of the foot and transmitted upward and backward by the mesial metatarsals, while at the same time the astragalus is forced downward and forward by the body weight. If, at this moment, the foot rolls over into inversion or eversion, the head of the astragalus may become disengaged from its articulation with the scaphoid, and dislocation follows.

Varieties of Dislocations.—If the internal and external lateral ligaments of the ankle give way between their points of attachment to the astragalus and to the os calcis, the foot dislocates at the subastragaloid joint, the astragalus retaining its normal position in the mortise of the ankle-joint. If, on the other hand, these ligaments remain intact, and only the short fibres which pass from the malleoli to the astragalus give way, the latter bone may be extruded from its position between the os calcis and the ankle and a complete or total dislocation of the astragalus result.

It is, therefore, necessary to differentiate between incomplete or subastragaloid dislocations and total or complete dislocations of the astragalus.

1. INCOMPLETE OR SUBASTRAGALOID DISLOCATION

Types of Displacement.—These are usually divided into the anterior, posterior, mesial, and lateral varieties, the terms being applied to the position of the astragalus with reference to the foot (Fig. 690). The pure anterior type, in which the head of the astragalus lies on the superior surface of the scaphoid, is very rare. The mesial and lateral types are very much more common and are determined by whether the foot was everted or inverted

at the moment of injury. They are accompanied by anterior displacement as well, the head of the astragalus lying to the inner or outer side of the scaphoid. The posterior variety is seldom encountered.

Diagnosis.—The diagnosis does not present great difficulty, except for the rarity of the lesion, if a careful attempt is made to analyze the deform-

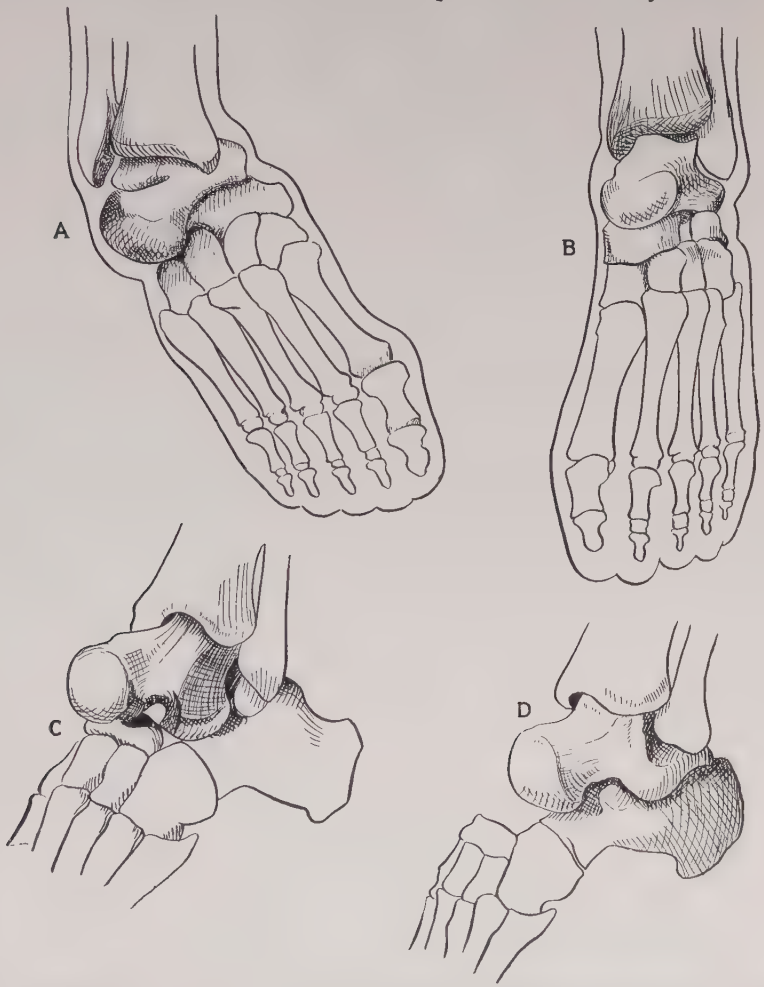


FIG. 960.—Subastragaloid dislocation. (A) Outward. (B) Inward. (C) Forward. (D) Backward. (After Hoffa.)

ity. The foot is usually in the position of marked inversion or eversion, and there is a characteristic bulge produced by the head of the astragalus. The forefoot is shortened and the heel lengthened. Swelling is great and there may be circulatory disturbance. Fracture of the astragalus may be confused with this condition and Roentgen examination is necessary for the purpose of differentiation.

961 962 963

FIGS. 961, 962 and 963.—Incomplete dislocation of the astragalus. (961 and 962) Before reduction. (963) After reduction. A good functional result was obtained. (Edinburgh Royal Infirmary.)

2. TOTAL DISLOCATION OF THE ASTRAGALUS

Displacement.—Total dislocation of the astragalus is a rare occurrence. It is usually displaced forward and outward and the injury may be compound. Other recognized varieties of the dislocation are the forward and inward, the anterior, the posterior, and the oblique, the terms being used

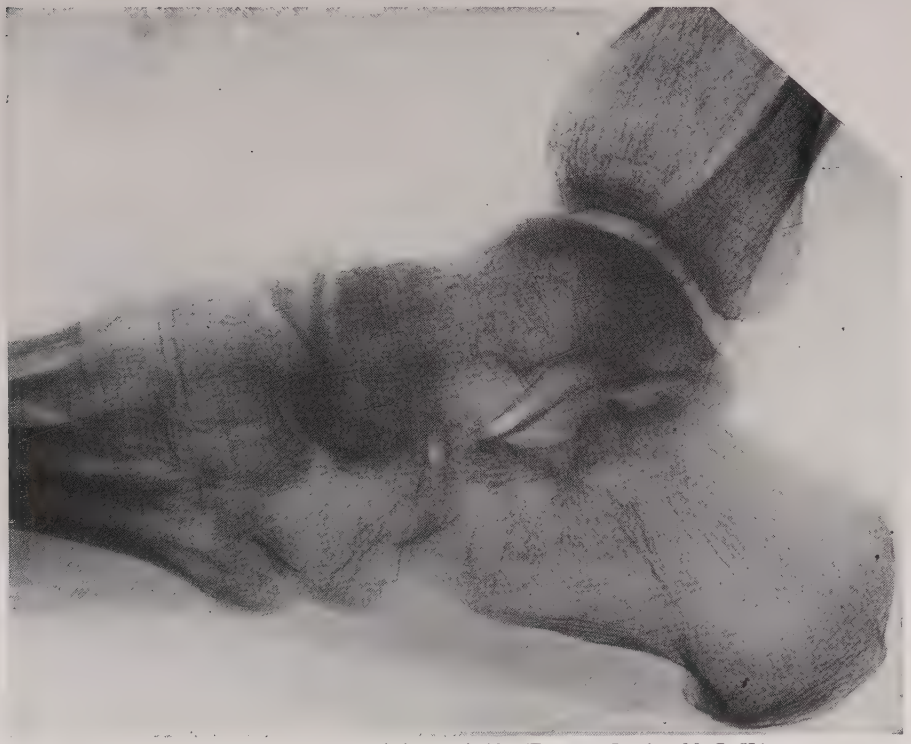


FIG. 964.—Crush fracture of the scaphoid. (Fracture Service, M. G. H.)

to describe the displacement of the astragalus. The diagnosis can usually be made only from roentgenograms.

Treatment.—In both the incomplete and total types of dislocation, immediate reduction should be attempted, but this procedure has proved much more successful in the former than in the latter.

Reduction of the Subastragaloid Dislocation.—In the former the main point in reduction is first to increase the deformity before attempting replacement. Thus, in the outward type with the foot in inversion, first increase the inversion, then, while maintaining this position, make local pressure on the head of the astragalus in a backward and inward direction while at the same time pulling the foot forward. In old-standing cases, operative reduction is indicated, aiming at a subastragaloid arthrodesis in good position.

Reduction of Total Dislocation of the Astragalus.—In the total dislocation, the os calcis lies in contact with the malleoli, and it is necessary to pull it away by the employment of strong manual traction in order to open up the bed for the astragalus and allow replacement. It is difficult to accomplish this successfully, and, reduction failing, the operation of astragalectomy has generally been performed. It should be remembered, however, that removal of the astragalus in the adult almost always leaves a permanently crippled foot and that reduction is infinitely preferable.

It would seem probable that reduction might be obtained in more cases if preliminary tenotomy of the tendo Achillis was performed. The one positive indication for astragalectomy is a compound dislocation in which the head of the astragalus has become soiled, and there is little hope of being able to disinfect it and return it to its socket.

After-treatment.—In both types of dislocation there is little tendency for the deformity to recur if replacement has been obtained. The foot should be fixed for a period of three to four weeks in the position of inversion and right-angle flexion by a plaster boot extending from the toes to the ankle. Massage and active movement should be begun immediately by splitting the cast and then continued daily. After removal of the cast, the foot should be protected by the application of a stirrup adhesive strapping. Weight-bearing with a Thomas heel and high boot may be permitted at the end of six weeks, provided there is no accompanying fracture.

IV. FRACTURE OF THE BONES OF THE ANTERIOR TARSUS

Fracture of the Scaphoid.—Fracture of the scaphoid is not infrequent and usually follows a fall, in which the astragalus is driven downward and forward against the resistance of the forefoot. The scaphoid is crushed as a result of the convergence of the two forces. In such fractures there is usually comminution and flattening, but the fragments remain in contact (Fig. 964).

Fracture of the Other Tarsal Bones.—The cuboid is occasionally fractured by direct violence. Fracture of the other tarsal bones occurs so rarely as scarcely to deserve mention. The bones are small and protected by the flexibility of the numerous surrounding joints. A crushing force is required to produce injury, and in such cases the soft parts as well as the bones are likely to be damaged to such an extent as to necessitate amputation. Comminution with but little displacement is to be expected.

Treatment.—The treatment of tarsal fractures consists chiefly in fixation by the use of a plaster of Paris boot, combined with early massage and movement. The chief danger is from traumatic flat-foot, and this may be prevented by care in supporting the plantar arch and in holding the foot slightly inverted and at right-angle flexion during the application

of the plaster. Weight-bearing should not be permitted until the end of six weeks, and then only with a carefully modeled steel arch support made from a plaster impression of the patient's foot. Full return of function can scarcely be expected before the end of eight or ten weeks. Rarely

Fig. 965.—Avulsion fracture of the inner portion of the scaphoid. (Fracture Service, M. G. H.)

it may be necessary, by open operation, to remove a small, displaced fragment of bone which causes painful boot pressure.

V. MEDIO-TARSAL DISLOCATIONS

Varieties.—Dislocation at the articulations between the os calcis and astragalus on the one hand and the anterior tarsal bones on the other occurs very rarely (Fig. 966). Total and incomplete types have been described. In the former the forefoot is displaced downward and backward, in the latter it is partially displaced in either the mesial or lateral directions. The injury may be compound and may end in amputation.

Treatment.—Reduction should be attempted, but is not likely to be completely successful, and considerable disability is apt to ensue. Later, operative remodeling of the bones may be necessary. The cardinal points are support of the plantar arch and prevention of weight-bearing for at least eight to ten weeks.

VI. TARSO-METATARSAL DISLOCATIONS

Varieties.—Pure dislocation at the tarso-metatarsal articulation without associated fracture of the tarsus or metatarsus is a very rare injury. The cause has usually been direct violence from a run-over accident or the fall of a heavy object, but forcible flexion of the forefoot has also produced the injury. Either a single metatarsal or the entire metatarsus may be luxated. In the latter case the dislocation may be of the anterior variety, the bases of all the metatarsals being displaced upon the dorsum of the tarsus, or it may be of the divergent type, the mesial metatarsals displacing inward and the lateral metatarsals outward (Figs. 967–971).

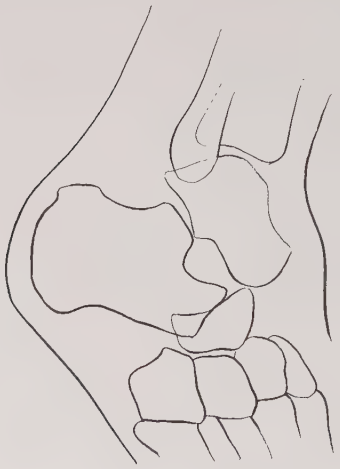


Fig. 966.—Mediotarsal dislocation.

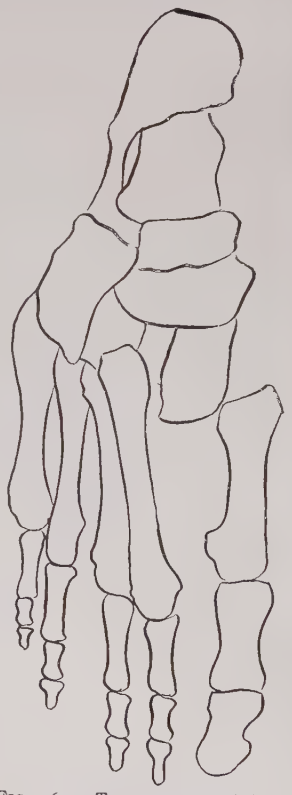


Fig. 967.—Tarso-metatarsal dislocation. Divergent type.

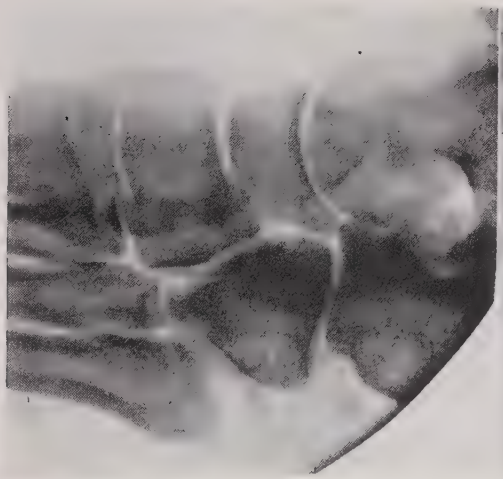
Treatment.—It is obvious both from the subcutaneous position of the bones and the severe degree of violence required that these injuries are very likely to be compound and may often end in amputation. Operative cleansing of the wound and replacement of the bones should be practised whenever possible. This should be followed by prolonged immobilization in a plaster of Paris boot. Traction may prove advantageous and can be secured by incorporating a wire hoop frame in the foot portion of the cast, the extension being applied to the toes (Fig. 976).

VII. FRACTURE OF THE METATARSAL BONES

Occurrence and Types of Fractures.—Fracture of one or more of the metatarsal bones is a fairly frequent injury and may result from either direct or indirect violence. Direct violence, while it may be responsible for

968

969



970

971

FIGS. 968, 969, 970 and 971.—Dislocation of the bases of the second, third and fourth metatarsals caused by violent inversion of the foot. (968 and 969) Roentgenograms of original deformity. (968) Lateral view. (969) Antero-posterior view. (970 and 971) Roentgenograms following open reduction, and fixation in plaster. (970) Lateral view. (971) Antero-posterior view.

the fracture of a single metatarsal, particularly in the fifth, which occupies an exposed position at the outer border of the foot, is much more likely to produce multiple fractures of the metatarsus. Indirect violence, which was formerly considered an unimportant factor, has been shown to play rather

a large part in causing fracture of one or several of the metatarsals. This type of injury may result from the sudden impact of the body weight on the toes, as in jumping or running, and is particularly common among soldiers. In such cases the second metatarsal is most frequently involved. The fifth metatarsal may also be fractured by violent inversion of the foot, usually obliquely near its base (Figs. 972–975).

Treatment of Fracture of a Single Metatarsal.—When a single metatarsal alone is involved, there is but little tendency to displacement, and in

FIG. 972.—Fracture of the fifth metatarsal.

this respect it differs markedly from the corresponding fracture in the hand. For treatment, fixation in a plaster boot suffices. Care must be exercised to begin massage and active movements of the various joints of the foot within a few days, and over-treatment must be avoided. Union should be firm in four weeks, and weight-bearing may be permitted in five or six weeks.

Multiple Fractures of the Metatarsals.—Displacement is apt to be much more serious in cases with multiple fractures of the metatarsals. The shaft of one bone may swing over into contact with another, and synostosis or cross union and excessive callus formation are frequent results. In the more severe crushing injuries, all the metatarsals may be fractured or

there may be an accompanying dislocation of one or more of the toes at the metatarso-phalangeal articulation.

Treatment by Traction.—When displacement exists, it should be corrected. In simple cases this may be accomplished by the use of traction. A banjo splint, similar to the one used in injuries of the hand, is employed. This is made by incorporating the ends of a steel wire arch or hoop, extending distally beyond the toes, into the foot piece of a plaster boot (Fig. 976). Adhesive strips are applied to the toes, corresponding to the

FIGS. 973 and 974.—Fracture of the shaft of the second and third metatarsals. This injury was caused by jumping. (Fracture Service, M. G. H.)

displaced metatarsals, and traction obtained by the use of strong rubber elastic bands or pieces of light rubber tubing running from the toes to the wire hoop.

Open Reduction.—Traction is less efficient, however, when applied to the toes than to the fingers, chiefly due to the fact that the former are so much smaller and present little skin surface for fixation of the adhesive strips. Strong extension is apt to pull off the adhesive. For this reason, in the severe cases of multiple fracture of the metatarsus with complicated displacement, open reduction is frequently indicated. Fixation is obtained with a plaster boot, and the after-treatment is the same as in the cases of simple fracture without displacement. Weight-bearing should scarcely be

permitted before the end of four to six weeks, and then only with the anterior arch supported by a carefully modeled steel arch-plate.

VIII. FRACTURE OF THE PHALANGES

Causation.—Fracture of the phalanges is produced usually by direct violence. The proximal phalanx of the little toe is frequently broken as a result of "stubbing the toe" against a piece of furniture while walking barefooted in the dark. Fracture of the other toes, particularly the ter-

Fig. 975.—Fracture of the shaft of the fourth metatarsal.

minal phalanx of the great toe, usually results from the fall of a heavy object. In such cases the bone is crushed and comminuted, and the injury may be compound. As a rule, such injuries are but slightly disabling, and the end result is almost always good. There is but little tendency for displacement to occur (Fig. 977).

Treatment of Fracture of the Great Toe.—In the case of the great toe, it is best to apply a wooden splint the width of the toe and about four to five inches long, extending on the plantar surface from the tarso-metatarsal junction to the tip of the toe. This should be abundantly padded, so that it conforms to the irregular surface against which it is placed, and it is fixed with adhesive strips and bandage. The patient may be permitted to walk, bearing the weight on the heel and outer border of the

foot. At the end of two weeks the splint may be removed and adhesive strapping applied in the form of a spica around the toe and ball of the foot, the former being padded with felt. The sole of the shoe should be reinforced by an extra layer of stout leather applied by a cobbler. This stiffens the shoe and splints the toes, and walking can be performed without discomfort.

Treatment of Fracture of the Outer Four Toes.—In the case of fracture of one of the other four toes, sufficient fixation may be obtained by strapping it to the adjoining toes, cotton pads being interposed. With the thick reinforced sole and a large loose shoe, the injury causes but slight interference with the function of the foot even at the beginning. Union is usually solid at the end of three or four weeks, and the strappings and bandage may be discontinued. Hot foot-baths and the thick sole should be used until convalescence is complete.

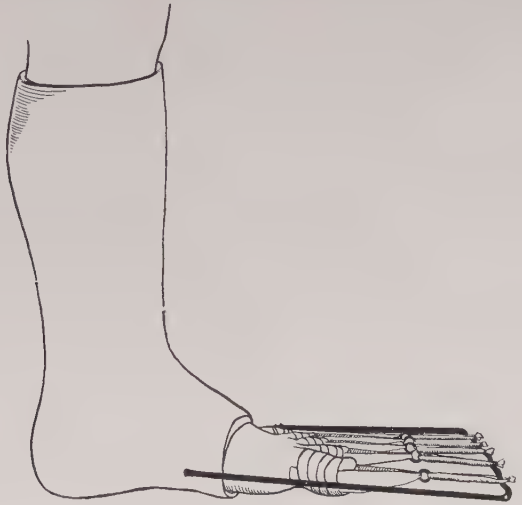


FIG. 976.—Banjo splint for foot, to secure extension on the toes as in a case of extensive fracture of the metatarsals. The wire frame is incorporated in a plaster boot.

IX. FRACTURE OF A SESAMOID OF THE GREAT TOE

Occurrence.—Of late years, fracture of the sesamoids has aroused considerable interest, and considerable literature has appeared on the subject. It seems to have been conclusively shown that either one of the sesamoids of the great toe may be fractured. The mesial one, lying in a more exposed position than the outer one, is the more frequently injured. The cause may be a blow which causes abduction and dorsiflexion of the toe or a fall of considerable violence upon the front of the foot.

Diagnosis.—In order to make the diagnosis, which is based chiefly upon the Roentgen examination, it is necessary to rule out a congenitally

bipartite condition of the sesamoids, which exists quite frequently and gives the appearance of fracture. The latter condition is apt to be bilateral, and the sesamoid is cleft into two nearly equal parts, the line of division being transverse or longitudinal. In fracture the condition is usually

FIG. 977.—Multiple fracture of the toes. This was an injury by direct violence. Note that all the terminal phalanges were fractured. (Edinburgh Royal Infirmary.)

unilateral, the line of division slightly irregular instead of smooth, and there may be comminution, the latter being almost a pathognomonic sign (Fig. 978).

Many of the cases have been seen a considerable time after injury when the evidences of acute trauma have subsided, and only the persistence of localized pain on use of the foot has led the patient to seek advice. In the acute condition, there is moderate swelling, disability, and tenderness. In the old cases, tenderness on pressure over the sesamoid is the chief sign.

Treatment of Recent Fracture.—In the acute cases the treatment should consist in complete immobilization of the foot and toes by the use of a plaster of Paris boot. This seems rather radical treatment for a comparatively minor injury, but experience has shown that these fractures usually

fail to unite when incompletely immobilized, and in that case persistent disability is the rule. Only by complete fixation of the foot, as well as of the toe, can muscular action exerted on the sesamoid be controlled. Fixation should be maintained for three weeks, at the end of which time

FIG. 978.—Fracture of the internal sesamoid, left foot. Note the three fragments into which the sesamoid is divided. The right internal sesamoid is congenitally bipartite.

weight-bearing may be permitted with a reinforced sole to prevent dorsiflexion of the toe and the anterior arch well padded with felt to relieve the sesamoid of direct pressure.

Treatment of Old Fracture.—In the old untreated cases the pain can often be relieved by the application of a steel arch support with a well-marked elevation under the anterior arch to relieve the pressure on the sesamoid. If this fails, it will be necessary to perform an operation for the purpose of excising the bone. Care must be exercised to avoid severance of the tendon in which it lies.

X. DISLOCATION AT THE METATARSO-PHALANGEAL ARTICULATION

Varieties and Displacement.—The toe most commonly affected by this injury is the great toe, the usual causes being a fall upon the toe or violence applied directly to the end of the toe, as in kicking a hard object. The base of the phalanx is usually displaced forward and outward, so that it lies on the dorsal and outer surfaces of the metatarsal head. If there

is considerable displacement, the flexor tendon of the toe may slip over the head of the metatarsal and constitute a serious obstacle to reduction. The injury is not infrequently compound, the head of the metatarsal projecting through the skin. The other toes are less frequently dislocated than the great toe, and the accident is usually produced by striking the end of the toe against a hard object. Mention has already been made (see p. 767) of the frequent association of dislocation of one or more of the toes with extensive fractures of the metatarsal region.

The diagnosis of dislocation is usually readily made from the appearance of the deformity alone, the position of the bones, on account of their subcutaneous situation, being readily recognizable.

Reduction.—Reduction of a dislocation of the four lesser toes is usually readily accomplished by traction on the toe and counter-traction on the foot, anæsthesia being unnecessary. Reduction in the case of the great toe is more difficult, and it is advisable to employ an anæsthetic. The manipulation consists in increasing the deformity, while at the same time pushing the base of the phalanx distally until it slips over the bulge of the metatarsal head. In rare cases, when the flexor tendon or other tissue becomes interposed between the two bones, open reduction is necessary, exposure being obtained by a dorsal incision.

After-treatment.—When reduction is accomplished by the closed method, there is little tendency for recurrence. Complete fixation is, therefore, unnecessary, and it is usually sufficient to apply an adhesive strapping or bandage for a few days to a week, after which full use may be allowed. A reinforced sole promotes ease of walking during the early stage of convalescence. Complete restoration of function may usually be expected, provided that too long fixation is not employed.

XI. DISLOCATION OF THE PHALANGES

Occurrence and Treatment.—The toes are rarely dislocated at the interphalangeal joints because of the extreme flexibility of the neighboring articulations, which prevents strain from affecting them. This is less true of the great toe, which has only one interphalangeal joint, than of the other four, and in consequence we find that when this injury does occur, it is the terminal joint of the great toe that is usually affected. Such an injury may be compound. Its reduction by traction and counter-traction presents no special difficulty and should be followed by the application of a wooden plantar splint as in the case of fractures of one of the phalanges of the great toe. Fixation should be more complete and maintained for a longer time than in the case of dislocation at the metatarsophalangeal joint, because of the more exposed position and greater instability of this articulation in comparison with the former. Massage and supported movements should, however, be commenced immediately.

INDEX

Acetabulum, anatomy of, 447
fracture of, 429, 446
with intrapelvic displacement of head of femur, 447, 472
after-care, 477
causation, 472
diagnosis, 475
fixation, 477
open reduction, 479
pathology, 473
prognosis, 479
reduction, 476
traction, 477
Acromio-clavicular joint, anatomy of, 61
dislocation of, 74
diagnosis of, 74
mechanism of, 74
treatment, 75
varieties, 74
Active motion, 12
Adams, 351, 547, 551
Adhesive plaster strapping in fracture of rib, 419
(See also under Treatment of Separate Bones and Joints)
Adolescent rickets, 479
Aeroplane splint, 58, 107, 111
Cleary, 112, 125
Allen, A. R., 384
Allis, O. H., 459
Allis's method of treating dislocation of hip, 465
Ambulatory treatment in fracture of clavicle, 70
Amputation in compound injuries of ankle, 729
with reference to compound fractures, 57
Anæsthesia in fracture of neck of femur, 505
in fracture of shaft of femur, 547
in wound treatment in cases of potentially infected compound fracture, 52
Anaphylaxis, avoidance of, 50
Anatomic form, relation of, to function, 4
Ankle, anatomical considerations, 689
compound injuries of, 689, 727
amputation in case of sepsis, 729
emergency treatment, 727
fixation, 728
operative treatment, 728
fractures of, diagnosis, 704
fracture with displacement, 705
fracture without displacement, 705
history of injury, 704
localized tenderness, 706
roentgen examination, 708
Ankle, fractures of, treatment, 708
after-treatment, 714
convalescent treatment, 718
fractures without displacement, 712
general principles, 708
incomplete reduction, 719
manipulative reduction, 710
methods of closed reduction, 711
non-union, 721
old malunited fractures, 721
physiotherapy, 715
roentgen examination, 714
skeletal traction, 720
splinting, 713
injuries in region of, 689
lateral ligaments of, 689
optimum functional position of, 692
sprain of, 689, 692
after-treatment, 696
causation, 692
diagnosis, 692
stirrup adhesive strapping, 696
treatment, 692
sprain-fracture of, 692, 701
Ankle-joint, anterior dislocation, 725
causation and pathology, 725
fixation and after-treatment, 726
reduction, 725
dislocations of, 689, 721
dislocation in antero-posterior plane, 721
dislocations in lateral plane, 721
varieties, 721
fractures of tibia and fibula involving, 689, 697
classification according to mechanism, 697
fracture by external rotation of foot, 689, 699, 711
(mechanism and pathology, 699)
fracture by abduction of foot (Pott's fracture), 689, 699, 700, 711
(mechanism and pathology, 700)
fracture by adduction of foot, 689, 699, 701, 711
(mechanism and pathology, 701)
fracture by posterior displacement of foot, 689, 699, 702, 711
(mechanism and pathology, 702)
varieties of fracture, 697
movements of, 690
ossification of, 691
posterior dislocation of, 724
diagnosis, 724
reduction, 725
separation of epiphyses at, 704
Ankylosis, optimum position for, 8

Arch supports in foot strain, 740
Arm, upper, anatomical considerations, 129
Ashhurst, A. P. C., 185, 699
and Bromer, R. S., 697
Astragalus, anatomy of, 689
fractures of, 731
of body, 744
of neck, 745
types of fracture, 744
reduction of total dislocation of, 762
Atlas and axis, traumatic lesions of, 343, 347
roentgenologic examination of, 350
treatment of, 350
dislocation of, with fracture of axis, 348
fracture of, 348, 349
diagnosis, 350
simple rotary dislocation of, 348
Avulsion fractures of femoral condyles, 587
of posterior portion of os calcis or separation of epiphysis, 745
causation and displacement, 745
treatment, 745
Axhausen, G., 635
Axis and atlas, traumatic lesions of, 343, 347
roentgenologic examination of, 350
treatment of, 350
dislocation of atlas, with fracture of, 348
Ayer, J. B., 377, 378

Back strain and bad posture, 339
Baldwin, W. I., 326
Balkan frame, 17, 109, 440
Bandage, hyperflexion, 166, 173, 187, 195, 197, 202, 204
Banjo traction splint, 58, 767
Bankart, A. S., 97
Bartel, 436
Barton jaw bandage, 407
Barton's fracture, 288
reversed, fracture of anterior articular margin of radius, 292
Baseball finger, 250, 319
Beasley, 547
Bed sores in lesions of spinal cord, 389
Bell, Charles, 347
Bennett, G. E., 577
Bennett's fracture, 250
displacement and diagnosis, 307
treatment, 308
Bigelow, H. J., 458, 460, 463
method of treating anterior dislocation of hip, 464
method of treating posterior dislocation of hip, 465
B. I. P. paste, 45
Bircher, 624
Bizarro, A. H., 295
Bladder and rectal disturbances in total transverse lesions of spinal cord, 378
care of, in lesions of spinal cord, 389
rupture of, in injuries of pelvis, 433
Blake suspension traction, 58, 128, 199, 214
Boeckel, A. and J., 342
Bone repair, 2
Bone-graft in non-union, 21
operation in ununited fracture of neck of femur, 512
of shaft of femur, 574
Bones, fractured, treatment of, 54
Bowel, care of, in lesions of spinal cord, 390
Brace, convalescent, in treatment of fracture of neck of femur, 501
short caliper, in fractures of tibia alone and of tibia and fibula combined, 678
Brackett, E. G., 512, 612
and Osgood, R. B., 636
operation for ununited fracture of neck of femur, 512
Bradford, E. H., 505
Bradford frame, 31, 35, 58, 357, 368, 372, 374, 387, 388, 391, 439, 440, 482, 569
Bromer, R. S., and Ashhurst, A. P. C., 697
Buck's extension, 490, 493
Burrell, H. L., 383
Bursa, subdeltoid, anatomy of, 85
Buzzard, E. F., 382

Cabot posterior wire splint, 31, 32, 38, 440, 610
Calcaneo-astragalo-scaphoid articulation anatomy of, 733
dislocations of, 731, 758
mechanism of dislocation, 758
varieties of dislocation, 758
incomplete or subastragaloid dislocation, 731
diagnosis, 759
types of displacement, 758
total dislocation of astragalus, 731, 761
after-treatment, 762
displacement, 761
reduction of subastragaloid dislocation, 761
of total dislocation of astragalus, 762
treatment, 761
Caliper brace, short, in fracture of tibia alone and of tibia and fibula combined, 678
splint in fracture of shaft of femur, 567
Calipers, application of, in fractures of shaft of femur, 549
or ice tongs, use of, in fractures of shaft of femur, 546
Callus formation, factors influencing, 2
Campbell, W. C., 493, 494, 512
Carpal bones, dislocations of, 304
fractures of, 304
injuries, 250, 295
mechanism of, 254
joints, motion of, 254
Carpo-metacarpal dislocations, 250, 305
joints, anatomy of, 253
motion at, 255

Carpus, anatomical variation in, 257
fractures and dislocations of, 250, 304
treatment of, 304
Carrel, 15
Carrel and Dehelly, 42
Carrel-Dakin method, 41, 42, 127, 153, 577, 683
"Cart-wheel" fracture, 588
Cauda equina, lesions of, 381
Cervical dislocation, 343
Championnière, Lucas, 2, 8, 10
Chauffeur's fracture, 263, 265
Chest wall, open wounds of, 412, 425
respiratory effects, 425
treatment, 425
Cheyne, 263
Chondromas, synovial, and osteomas in knee-joint, 636
Chordotomy, possibilities of relief by, in spinal cord injuries, 384
Clairmont, P., and Ehrlich, W., 97
Clavicle, anatomy of, 59
dislocations of, 73
fracture of, 63
causation, 63
diagnosis, 63
displacement, 63
in infants, treatment of, 72
radiographic examination, 67
treatment, 68
method of fixation in, 58
Clavicular cross, 58, 70
Cleary aeroplane splint, 112, 125
Clove-hitch, 32, 35
Coccyx, fracture of, 429
isolated fracture of, 446
Codman and Chase, 298, 299
Colles, 262
Colles's fracture, 226, 250, 262, 263, 288, 294
diagnosis, 268
incidence, 263
mechanism of injury, 263
reversed (Smith's fracture), 250, 263, 290
with displacement, 268
after-treatment, 280
choice of splints, 277
Cotton-Loder position, 276
fixation, 274
Jones method of reducing, 272
luxation of ulna, 283
malunion, 283
open reduction, 282
prognosis, 281
reduction, 272
without displacement, 259
roentgenologic examination, 271, 280
treatment, 271
Colvin, A. R., 635
Complicating conditions in compound injuries, influence of, 50
Compound fractures (See also Separate Bone and Joint Headings)
Compound fractures, amputation with reference to, 57
and dislocations, relation of infection to, 38
problems of treatment, 38
with potentially infected wounds, treatment of, 52
with uninfected wounds, treatment of, 51
injuries (See also Special Bone and Joint Headings)
injuries, 47
clinical examination, 48
complicating conditions, 50
different types, 47
wound produced by external violence, 47
wound produced by internal violence, 48
treatment, 49
Condyloid process of jaw, fracture of, 405
Cooper, Sir Astley, 485
Cord and vertebral lesions, association of, 342
lesions of cervical enlargement of, 380
Corlette, C. E., 444
Corner, Edred M., 348, 349
Coronoid process, fracture of, 154, 206
Costal cartilage, fracture of, 412, 421
Cotton, F. J., 276, 704, 755
Cotton-Loder position in Colles's fracture, 276, 280
Crile traction splint, 58, 519
Cuboid, fracture of, 762

Dakin's solution, 389
Danforth, M. S., 326
Davis, G. S., 359
Davison, C., 512
Débridement, 40, 153, 214, 306, 321
in compound fracture of femur, 577
of tibia and fibula, 683
open reduction following, 56
Deformity, disabling, in relation to function, 4
situation of, in relation to function, 4
Delbet, P., 674
plaster splint, 676
Depage, 40
Displacement, lateral, correction of, in fractures of shaft of femur, 563
Dorrance, G. M., 494
Drop finger, 319
Drummond, J., 539
Dugas's sign in dislocation of shoulder, 91
Dupuytren's fracture, 697, 700

Elbow, anatomical considerations, 154, 155, 156, 157
carrying angle of, 161
compound fractures of, 214
dislocations of, 154
etiology, 162
varieties, 162
examination of, 161

Elbow, method of fixation in injuries of, 58
optimum functional position of, 161
posterior dislocation of both bones of, 164
after-treatment, 167
complications, 168
diagnosis, 165
mechanism, 164
old unreduced dislocations, 168
pathology, 164
treatment, 166
pulled (subluxation of head of radius), 174
Ely, L. W., 483
Emphysema, subcutaneous, 423, 424
Epiphyseal strain, 113
Epiphyses at ankle-joint, separation of, 704
Epiphysis, capital, of femur, separation of, 447
adolescent rickets, 479
diagnosis, 480
etiology, 479
mechanism, 480
treatment, 480
in lower end of humerus, separation of, 175, 179, 180, 182
lower femoral, separation of, 578, 588
diagnosis, 589
displacement, 588
reduction, 589
splinting, 590
lower radial, separation of, 250, 262, 285, 292
separation of, or avulsion fracture of posterior portion of os calcis, 731 745
causation and displacement, 745
treatment, 745
upper humeral, anatomy, 83
upper humeral, separation of, 101, 113
diagnosis, 113
displacement, 113
epiphyseal strain, 113
treatment, 116
upper, of tibia, separation of, 578, 597
radial, anatomy, 157
ulnar anatomy, 156
Excision of carpal semilunar, 303
of damaged and infected tissues, 53
of fragments of shoulder, 100
of knee in fracture of tuberosities of tibia, 595
of radial head, 205
of semilunar cartilages of knee-joint, 626
operative, of carpal scaphoid, 299
Exercise treatment of foot-strain, 741
Extension, Buck's, 490, 493
overhead, in fracture of femur in children, 569
Extra-osseous injury in fractures, 2

Face, injuries of bones of, 392
method of fixation in, 58
Femoral condyles, avulsion fractures of, 587
fractures of, 578, 584
intercondyloid or "T" fracture of, 584
manipulative correction with clamp, 586
operative fixation, 587
skeletal traction, 585
treatment, 584
epiphysis, lower, separation of, 588
diagnosis, 589
displacement, 588
reduction, 589
splinting, 590
Femur, capital epiphysis of, separation, 447, 479
adolescent rickets, 479
diagnosis, 480
etiology, 479
mechanism, 480
treatment, 480
compound fracture of, 577
fixation, 577
skeletal traction, 577
wound treatment, 577
intertrochanteric fracture of, 447, 513
occurrence, 513
pathology, 513
treatment, 513
lower end of, anatomy, 578
third of, treatment of fracture of, 558
middle third, treatment of fracture of, 556
neck of, fracture, 447, 483
anæsthesia, 505
bone graft operation in, 512
Brackett operation in, 512
causation, 483
causes of non-union, 485
combined traction method, 505
complications, 511
diagnosis, 489
displacement, 488
etiology, 483
fixation in relation to recovery of function, 493
fracture in young adults, 509
healing, 485
impacted fractures, 507
prognosis, 511
roentgen examination, 503
treatment, 490
of old age fractures, 490
types of, 487
ununited fractures, 511
value of fixation, 491
Whitman method of reduction, 493
Whitman operation in, 512
ossification of, 448
pertrochanteric fracture of, 447, 515
shaft of, anatomical considerations, 520
extensor muscles, 520
fascial arrangement, 520
femoral shaft, 520
hamstrings, 520
vessels, 520

Femur, shaft of, fractures, 520, 521
advantages of skeletal traction, 554
after-treatment, 561
in children, 571
anæsthesia, 547
application of calipers, 549
caliper splint, 567
correction of lateral displacement, 563
correction of shortening, 562
daily adjustment of apparatus, 565
dangers of skeletal traction, 551
diagnosis, 527
displacement, 525
fracture in lower third, 526
in middle third, 526
in upper third, 525
gradual correction of deformity, 561
hinged leg support, 549
lengthening of quadriceps tendon, 577
mobilization of knee, 566
nerve and vessel lesions, 528
nursing care, 566
open operative treatment, 573
overhead extension in children, 569
preparation of splint, 548
physiotherapy, 567
roentgen examination, 529
skeletal traction, 546
stiffness of knee, 576
support of foot, 545
treatment (general), 531
at different levels, 556
in children, 568, 571
of malunion, 574
of ununited fractures, 574
supracondylar fracture, treatment of, 559
upper extremity of, anatomy, 448
third, treatment of fracture of, 556
Fibula, anatomy of, 638
ossification of, 638
shaft, fracture of, unassociated with injury of ankle-joint, 638, 644
diagnosis, 644
types of and causation, 644
treatment, 644
Fibula and tibia, fractures of, involving ankle-joint, 689, 697
classification according to mechanism, 697
varieties, 697
by abduction of foot (Pott's fracture), 689, 699, 700, 711
by adduction of foot, 689, 699, 701, 711
by external rotation of foot, 689, 699, 711
by posterior displacement of foot, 689, 699, 702, 711
function of, 642
lower ends of, anatomy, 689
shaft of, fractures, 638
combined, fracture of, treatment, 650
anæsthesia in reduction of, 658
dangers in reduction of, 656
effect of alteration of normal weight-bearing lines, 651
fundamental rules in, 652
gravity method of reducing, 660
indications for closed reduction, 658
methods of obtaining alignment, 658
posterior splint method of reducing, 661
reduction and fixation, 654
relation of fracture to function of foot, 650
roentgenological examination, 661
technic of reduction, 658
time element in reduction, 655
Finger, baseball, 250, 319
drop or mallet, 319
traction, 326
Fingers, compound injuries of thumb and, 250, 321
fracture of phalanges, 250, 317
injuries of metacarpals and, 250, 307
interphalangeal dislocations of, 250, 317
method of fixation of, 58
treatment of, 325
Fisher, A. G. Timbrell, 635
Fixation, dangers of transportation without adequate, 27
external, methods of, 57
in Colles's fracture, 274
in compound fracture of femur, 577
injuries of ankle, 728
in compound fractures of ankle; clavicle; elbow; fingers; face; femur; foot, anterior tarsus; foot, posterior tarsus; forearm; hip; humerus (shaft); knee; leg; pelvis; scapula; shoulder; spine; thorax; toes; wrist and hand, 58
in compression fracture of vertebral bodies, 368
in dorsal luxation of proximal phalanx of thumb, 316
in fracture of acetabulum with intrapelvic displacement of head of femur, 477
of lower end of humerus, 187
of mandible, 407, 409
of olecranon process, 212
of os calcis, 755
of surgical neck of humerus, with displacement, 107
in lesions of spinal cord, 387
in relation to recovery of function in fracture of neck of femur, 493
in separation of capital epiphysis of femur, 482
in supracondylar fracture of lower end of humerus, 195
internal, 18
not advisable, 56

Fixation, length of time of, in treatment of fractures of neck of femur, 501
method of treatment, 6, 7
of shoulder in fracture of ribs, 420
of spine, optimum position for, 338
optimum positions for, 8
Flat-foot, pronated foot, foot-strain, 737
arch supports, 740
causes of foot-strain, 739
diagnosis, 738
exercise treatment, 741
faulty gait, 740
posture, 739
normal muscle balance, 738
pathology, 738
relation of traumatic and functional flat-foot, 737
treatment, 740
traumatic, in fracture of os calcis, 752
Flexion fractures of radius, 250
Foot, anatomical considerations, 731
arches, 731
calcaneo-astragalo-scaphoid articulation, 733
comparative importance of ligamentous and muscular support, 734
joints of toes, 733
movements of foot, 733
ossification of bones of foot, 734
skeletal arrangement, 732
structure in relation to function, 731
to trauma, 732
supporting function of muscles, 735
tarsal and metatarsal joints, 733
toes, 733
variations in bones of foot, 734
fractures and dislocations of, 744
injuries of, 731
dislocation of metatarso-phalangeal articulations, 731, 771
of phalanges, 731, 772
dislocations of calcaneo-astragalo-scaphoid articulation, 731, 758
fracture of astragalus, 731, 744
of bones of anterior tarsus, 731, 762
of metatarsal bones, 731, 765
of phalanges, 731, 768
of sesamoid of great toe, 731, 769
fractures of os calcis, 731, 745
medio-tarsal dislocations, 731, 763
tarso-metatarsal dislocations, 731, 764
lateral movements of, 691
limitation of lateral movements of, in fracture of os calcis, 752
support of, in fracture of shaft of femur, 545
Foot-strain, See Flat-foot
Forbes, 355, 371, 372
Forearm, anatomical considerations, 215
both bones of, fracture, 215, 228
after-treatment, 247
causation, 226
complications, 249
continuous traction, 233
dangers, 236
diagnosis, 227
displacement, 226
greenstick fracture, 247
prognosis, 247
splinting, 230
traction, 247
treatment, 244
treatment of fracture with displacement of, 228
without displacement of, 228
compound fractures of, treatment, 249
method of fixation in compound fractures of, 58
muscles of, 215
optimum functional position of, 220
single bone of, treatment of fracture with displacement of, 228
Foreign bodies, removal of, 54
Fracture committee, British Medical Association, 4
treatment, outline of, 24
Fractures and dislocations, functional viewpoint in treatment, 1
need of immediate treatment, 3
pathology in relation to treatment, 2
compound, 38
problems of treatment in, 38
Frames, Balkan, 17
Bradford, 31, 35
Morrison, 17
overhead, 17
Rainbow, 17
Function, optimum position for, 8
relation of anatomic form to, 4
Functional viewpoint of treatment, 1
position, optimum, of shoulder, 86

Gait, faulty, in foot-strain, 740
Gallie, 613
Glue, Heusner's, 14
Sinclair's, 14
application of, 15
Glued stocking, 664, 669
Goldthwait, J. E., 96, 610, 612, 613
Graft, bone, in non-union, 21
in ununited fractures of shaft of femur, 574
Gravity method of reducing fractures of tibia alone and of tibia and fibula combined, 660
Gray, H. M. W., 40
Great toe, sesamoid of, fracture, 769
treatment of fracture of, 768
Greenstick fracture of both bones of forearm, 224, 247
Gunshot injuries of mandible, 411
Gurtt, 383

Hæmothorax, 422
Hammond interdental splint, 408

Hand, arches of, 258, 259
and wrist, anatomical considerations, 250
injuries of, 250
landmarks in region of, 261
method of fixation in, 58
optimum functional positions of, 261
ossification of, 257
flat, prevention and treatment of, 260
Hands, stiff, physiotherapy in, 325
treatment of, 250, 323
Hartley, J. N. J., 347
Hawley pin, 671
Head, H., and Riddoch, G., 382
Heel, lateral displacement of, in fractures of calcis, 752
Henderson, M. S., 493, 637
Hesse, 483
Heusner's glue, 14
Hey Groves, E. W., 630
Hibbs, 355, 371, 372
Hinged leg support in fracture of shaft of femur, 549
Hip, anatomy of, 447
acetabulum, 447
bony landmarks, 451
capsule, 450
ilio-femoral ligament, 451
muscles, 451
optimum functional position, 456
ossification of femur, 448
round ligament, 449
upper extremity of femur, 448
vessels and nerves, 451
anterior dislocation, Bigelow's method of treating, 464
bony landmarks of, 451
capsule of, 450
compound injuries of, 519
dislocation of, 447, 457
after-treatment, 468
Allis's method of treating, 465
anterior dislocation, 458
diagnosis, 460
etiology, 457
mechanism, 458
pathology, 459
posterior dislocation, 458
Stimson's method of treating, 466
treatment, 463
fracture-dislocation of, 470
habitual recurrent dislocation of, 470
injuries of, 447
method of fixation in compound fractures of, 58
muscles of, 451
old unreduced dislocations, treatment of, 469
optimum functional position of, 456
pathological dislocation of, 471
posterior dislocation of, Bigelow's method of treating, 465
round ligaments of, 449
vessels and nerves of, 451
Hodgen's splint, 493
Hood, Wharton, 10
Humeral epiphysis, upper, displacement of, 101, 113
diagnosis, 113
treatment, 116
strain of, 113
Humerus, anatomical neck, fracture of, 101, 120
diagnosis, 120
treatment, 120
compound fracture of, 151
greater tuberosity of, fracture, 124
diagnosis, 124
displacement, 124
etiology, 124
prognosis, 127
treatment, 125
lower end of, anatomy, 154
fracture of condyles or epicondyles, diagnosis, 181
of epicondyle, 154, 175, 178, 202
of single condyle, 154, 175, 197
displacement, 177
mechanism, 177
prognosis, 197
fractures of, 154, 175
circulatory disturbance, 188
diagnosis, 180
flexion in treatment, 185
increasing fractional movements, 191
mobilization dressing, 191
treatment, 182
when to begin movement, 190
intercondyloid or "T" fracture, 154, 175, 178, 197
ossification of, 154
separation of epiphysis, 175, 179, 202
diagnosis, 182
special dangers, 180
supracondylar fracture, 154, 175
diagnosis, 180
etiology and displacement, 176
fixation, 195
prognosis, 195
treatment, 195
transverse diacondylar fracture, 154, 175, 176, 197
shaft of, fracture, 133
adhesive traction method, 142
amount of traction required, 144
anatomy, 129
causation, 133
convalescent splint, 148
correction of lateral displacement or angulation, 144
delayed union, 150
diagnosis, 133
displacement, 133
elbow traction method, 141
etiology, 133
method of fixation in compound fractures, 58
non-union, 150
physiotherapy, 148

Humerus, shaft of, prognosis, 149
radiographic examination, 148
step-cut operation, 151
suspension of splint, 142
treatment, 135
in infants and children, 149
triangular axillary splint with forearm rest, 148
surgical neck, fracture of, 101
diagnosis, 103
displacement, 103
etiology, 102
radiographic examination, 104
with displacement, 105
after-treatment, 110
fixation, 106
fixed and sliding traction, 109
suspension of splint, 109
treatment, 105
without displacement, 112
prognosis, 112
tuberosities of, fracture, 101
upper end of, injuries of, 101
Humphrey, 429, 483
Hyperextension fractures of lower end of radius, 250
Hyperflexion bandage, 166, 173, 187, 195, 197, 202, 204

Iliac crest, separation of, 443
spines, fracture of, 444
Ilio-femoral ligament, 451
Ilium, fractures of, 429, 442
ala of, fracture, 442
Infection, latent, in healed compound fractures, 46
relation to compound fractures and dislocations, 48
treatment of, in compound injuries of wrist, 306
wound, 38
Infrapatellar fat pad, injury of, 578, 617, 631
anatomical considerations, 631
causation and pathology, 632
diagnosis, 633
treatment, 634
Innominate bone, anatomy, 426
Intercondyloid or "T" fracture of femur, 584
manipulative correction with clamp in, 586
operative fixation, 587
skeletal traction, 585
treatment, 584
Interosseous ligaments of wrist, 253
Interphalangeal dislocations of fingers, 250 317
Intra-articular injuries, treatment of, 54
Ischium, fracture of, 429
isolated fracture of, 444
Ivy, R. H., 409

Jefferson, 349
Jones humerus traction splint, 31, 58, 136, 199
method of reduction of injury of semilunar cartilages of knee-joint, 625
R., and Smith, S. Alwyn, 631
Sir Robert, 13, 193, 197, 272, 622, 633, 634

Kemp, L. S., 505
Kleinberg, S., 352
Knee, anatomy, 578
dislocation, 578, 613
after-treatment, 615
diagnosis, 614
operative treatment, 616
pathology, 613
reduction and fixation, 615
varieties, 613
excision of, in fracture of tuberosities of tibia, 595
injuries in region of, 578
method of fixation in compound injuries of, 58
mobilization of, in treatment of fracture of shaft of femur, 566
movements of, 583
ossification of, 578
sprain-fracture of, 619
stiffness of, in fractures of shaft of femur, 576
Knee-joint, anatomy, 579
crucial ligaments, anatomy, 581
injury of, 578, 617, 627
diagnosis, 629
mechanism and pathology, 627
treatment, 630
external semilunar cartilage, injury of 623
infrapatellar fat pad, injury of, 578, 617 631
anatomical considerations, 631
causation and pathology, 632
diagnosis, 633
treatment, 634
internal derangements of, 578, 617
etiology, 617
lateral ligaments, anatomy, 581
injury of, 578, 617
loose bodies in, 578, 617, 634
diagnosis, 635
origin, 635
resulting from disease, 634
treatment, 636
posterior ligaments, anatomy, 582
semilunar cartilages, anatomy, 581
injury of, 578, 620
after-treatment, 626
causation, 620
diagnosis, 623
of old injuries, 624
of recent injuries, 623
excision of cartilage, 626

Knee-joint, semilunar cartilages, injury of, Jones method of reduction, 625
mechanism and pathology, 622
reduction, 625
synovial chondromas and osteomas, 636
tibial spine, fracture, 578, 617, 630
Kocher's method of reduction of shoulder dislocation, 94
König, 635
Kümmell, H., 371
Kümmell's disease (traumatic spondylitis), 371

Laminæ or spinous processes, isolated fracture of, 343, 355
diagnosis, 355
treatment, 355
Lane, W. Arbuthnot, 18, 19
Langenbeck incision, 199
Leg, fracture of both bones of, 638, 648
by direct violence, 648
by indirect violence, 648
causation, 648
diagnosis, 649
displacement, 648
injury of vessels and nerves, 649
muscles of, 642
Lemaitre, René, 40
Ligament, ilio-femoral, 451
orbicular, 159
Ligaments, crucial, of knee-joint, anatomy, 581
injury of, 578, 617, 627
diagnosis, 629
mechanism and pathology, 627
treatment, 630
lateral, of ankle, 689
of elbow, 159
of knee-joint, anatomy, 581
injury of, 578, 617
diagnosis, 619
mechanism and pathology, 617
treatment, 619
posterior, of knee-joint, anatomy, 582
Liston splints, long, 31, 33
Litter, snow-shoe, 31, 35
Loose bodies in knee-joint, 578, 617, 634
diagnosis, 635
origin, 635
resulting from disease, 634
treatment, 636
Lumbar puncture, 377
Lund swathe, 188, 202

Maddren, R. F., 319
Malar bone and zygomatic arch, fracture of, 392
anatomy, 397
diagnosis, 398
treatment, 398
types, 397
Malgaigne, fracture of, 431
Mallet finger, 319
method of reduction of fracture of os calcis, 755
Malunion, 20
in children, 5
in Colles's fracture, 283
in fractures of os calcis, treatment, 755
of shaft of femur, treatment, 574
of tibia alone and of tibia and fibula combined, treatment, 679
old, in fracture of ankle, 721
Mandible, anatomy, 400
body, 400
movements, 401
ossification, 401
ramus, 400
surface anatomy, 401
temporo-mandibular articulation, 401
dislocations of, 392, 402
diagnosis, mechanism, treatment, 402
fractures of, 392, 403
causation, 402
complications, 407
diagnosis, 406
fixation, 407
fracture of body, 404
of condyloid process, 405
of ramus, 405
of symphysis, 405
gunshot injuries, 411
interdental splint, 408
intraoral fixation with wire, 409
treatment, 407
injuries of, 392
Manipulation in injuries of pelvic ring, 440
Martin, A. M., 617
Massage, 8
action of, 10
and mobilization, 8
first use of method, 8
indications for use, 10
technic of, 11
Maxilla, superior, anatomy, 398
fractures of, 392
diagnosis, 399
production, 399
treatment, 399
types, 398
Maxwell, 479, 505
Mediotarsal dislocations, 763
treatment, 764
varieties, 763
Mennell, James B., 9
Metacarpal bone, base of first, Bennett's fracture, 307
bones, fracture of, 250, 303
shaft, displaced fractures of, 310
fracture of, 250
pathology, 309
treatment, 310
Metacarpals and fingers, injuries of, 250, 307
Metacarpo-phalangeal joints, dislocation of, 250, 313

Metatarsal bones, fracture of, 765
multiple fractures, 766
open reduction, 767
treatment by traction, 767
of fracture of single metatarsal, 766
Metatarso-phalangeal articulation, dislocation at, 771
after-treatment, 772
reduction, 772
varieties and displacement, 771
Minerva plaster jacket, 351, 356, 369
Mixter, S. J., and Osgood, R. B., 350, 351
Mixter, W. J., 383
Mobilization, 8
active motion in, 12
and massage, 8
first use of method, 8
dressing in fracture of lower end of humerus, 191
of knee in fracture of shaft of femur, 566
Morris, Henry, 429, 430
Morrison frame, 17
Morrison, Rutherford, 45
Mortality in lesions of spinal cord, 383
Motion, active, 12
Movement, increasing fractional, in lower end of humerus, 191
when to begin, in fracture of lower end of humerus, 190
Murphy, E. C., 494
Murray, 30
Muscle tissue, treatment of, 54
triceps, 161
Muscles of forearm, 215

Nasal bones, fracture of, 392
anatomy, 392
diagnosis, 395
treatment, 396
types, 394
Nélaton, 566
Nerves, posterior interosseous and ulnar, 160
New, Way Sung, 512
Nix, J. T., 491
Non-union, 21
in fracture of ankle, treatment of, 721
of shaft of humerus, 150
of tibia alone and of tibia and fibula combined, treatment, 650
operative treatment of, 21
use of bone graft in, 21

Olecranon process, fracture of, 154
diagnosis, 211
fixation, 212
mechanism, 206
pathology, 211
treatment, 211, 213
Open operative treatment, 6
dangers in, 19
of fresh fractures, 18
reduction following débridement, 56
in fracture of tibia alone and of tibia and fibula combined, 679
of fractures of metatarsal bones, 767
of os calcis, 755
Operation, step-cut, in fracture of shaft of humerus, 151
Operations, secondary, precautions in, 46
Optimum functional position of ankle, 692
of elbow, 161
of forearm, 220
of hip, 456
of shoulder, 86
position for ankylosis, 8
of fixation of spine, 338
positions for fixation and function, 8
time for operation in fractures of patella, 606
Os calcis, fractures of, 731, 745
fracture of body of, 731, 749
after-treatment, 755
diagnosis, 750
displacement, 749
fixation, 755
lateral displacement of heel, 752
limitation of lateral movements of foot, 752
mallet method of reduction, 755
obstacles to reduction, 754
open reduction, 755
pathology, 749
prognosis, 751
roentgen examination, 751
reduction, 754
skeletal traction method, 755
traumatic flat-foot, 752
treatment of malunited fractures, 757
fracture of sustentaculum tali, 731, 745
after-treatment, 748
diagnosis, 747
prognosis, 747
reduction, 747
separation of epiphysis or avulsion fracture of posterior portion of, 731, 745
causation and displacement, 745
treatment, 745
Osgood, R. B., 320
and Brackett, E. G., 636
and Mixter, S. J., 350, 351
and Surls, J. K., 617, 635, 636
Osgood-Schlatter disease, 599
Os magnum, fracture of, 304
luxation of, 304
Osteochondritis dissecans, 635
Osteomas and synovial chondromas in knee-joint, 637
Osteotomy for malunion in fracture of shaft of femur, 574
Overhead extension in fracture of femur in children, 569
frames, 17

Palmar arches and thumb, anatomy, 260
functional importance of, 258
Paralysis, radial nerve, 151
sphincter, in lesions of spinal cord, 390
Patella, anatomy, 578
dislocation, 578, 610
diagnosis, 611
operative treatment of recurrent dislocation, 612
outward dislocation, 610
predisposing causes, 610
recurrent dislocation, 611
single traumatic dislocation, 611
treatment of simple traumatic dislocation, 612
varieties, 610
fracture of, 578, 600
advantages of operative treatment, 604
after-treatment, 608
by direct violence, 600
by indirect violence, 601
conservative treatment in fracture with displacement, 603
diagnosis, 601
fibrous union *versus* bony union, 604
indications for operation, 605
non-operative method of treatment, 609
optimum time for operation, 606
technic of operation, 607
treatment, 603
Pathology in relation to treatment, 2
Pearson, 539, 547, 549
Pelvic injury, types of, 428
ring, fractures of, 429
association with other skeletal injuries, 437
diagnosis, 437
prognosis, 438
treatment, 439
isolated fracture of pelvic bones not affecting continuity of, 429
fracture of coccyx, 446
of ilium, 442
of ischium, 444
of sacrum, 445
multiple fractures of, 429, 431
Pelvis, anatomy, 426
innominate bone, 426
ossification, 427
sacro-iliac joints, 427
sacro-sciatic ligaments, 427
symphysis pubis, 427
injuries of, 427
injury of pelvic contents in, 433
isolated fracture of bones of, not affecting continuity of pelvic ring, 429
fracture of coccyx, 446
of ilium, 442
of ischium, 444
of sacrum, 445
method of fixation in compound fractures of, 58
Phalanges of fingers, dislocation, 317
fracture of, 250, 317
of toes, dislocation, 772
fracture, 768
causation, 768
treatment of fracture of four outer toes, 769
treatment of fracture of great toe, 768
Phemister, D. B., 623
Physiotherapy in fracture of ankle, 715
of shaft of femur, 567
of humerus, 148
of tibia alone and of tibia and fibula combined, 673
in stiff hands, 325
in Whitman method of treatment of fracture of neck of femur, 501
Pilcher, L. S., 264
Pillow and side splints, 36
Plantar splint, 58
Pleura, anatomy, 412
Pneumothorax, 423, 424
Popliteal nerve, external, 643
Posture and back strain, 339
in foot-strain, 739
Pott's disease, 366
fracture, 689, 697, 699, 700, 711
Pronated foot, See Flat-foot
Pubis, fracture of rami of, 429, 431
Putti, V., 575

Quadriceps tendon, lengthening of, in fractures of shaft of femur, 577

Radial epiphysis, lower, separation of, 285, 292
head, excision of, 205
nerve, anatomy, 131
paralysis, 151
wrist-drop in injury of, 134
styloid, fracture of lateral articular border of radius and, 262
tip of, 288
oblique fractures of lateral border of radius and, 285
causation, 285
treatment, 288
Radio-carpal articulation, anatomy, 252
joint, dislocation, 250, 294
causation, 294
diagnosis, 294
treatment, 295
Radio-ulnar joint, inferior, anatomical considerations, 250
chronic recurring luxation of, 294
dislocation, 250
pathology, 292
treatment, 293
Radius, anatomical considerations, 215
and radial styloid fractures of lateral articular border, 285
causation, 285
treatment, 288

Radius, Colles's fracture of, 250
displacement in fractures of, 265
flexion fractures of, 250
fracture of shaft of ulna associated with dislocation of head of, 215
head of, anterior dislocation, mechanism, 171
treatment, 173
irreducible posterior dislocation, 174
posterior dislocation, 154
treatment, 174
head and neck of, fractures, 154
displacement, 204
mechanism, 203
pathology, 204
treatment, 204
lower end of, complicated fractures, 262
epiphyseal separation, 250, 262, 263
fractures, 262
anterior marginal, 250, 263, 292
with posterior displacement of lower fragment, 262
without displacement, 262
hyperextension fractures, 250
outer articular border, oblique fracture, 250
posterior articular margin, fracture, 262, 288
diagnosis, 288
pathology, 288
treatment, 288
dislocation of ulna and, 154
marginal fracture of, 250
shaft of, fracture, 215, 222
causation, 222
complications, 244
diagnosis, 226
displacement, 225
prognosis, 244
shortening, 226
treatment, 242
Smith's fracture of (Colles's fracture reversed), 250
subluxation of, or "pulled elbow," 174
types of fracture of, 265
ulnar complications in fracture of, 267
upper end of, anatomy, 157
Rainbow frame, 17
Ramus of jaw, fracture of, 405
of pubis, fracture of, 429, 431
Ransohoff, 547
Recumbency in treatment of fracture of clavicle, 58, 68
Reduction of fractures, 6, 7
avoidance of, 51
open, following débridement, 56
Reflexes, prognostic value of, in lesions of spinal cord, 383
Reposition, importance of securing, 4
Ribs, anatomy, 412
fracture, 412
by direct violence, 414
by indirect violence, 415
complications, 417
diagnosis, 416
hæmothorax, 422
intrathoracic complications, 422
pneumothorax, 423
subcutaneous emphysema, 423
treatment, 418
of intrathoracic complications, 422
Riddoch, G., 382
Roberts, 290
Roentgenological examination, in Colles's fracture, 271, 280
in compound injury, 48
in compression fracture of vertebral bodies, 366
in fracture of ankle, 708, 714
of body of os calcis, 751
of carpal scaphoid, 298
of neck of femur, 503
of scapula, 79
of shaft of femur, 529
of humerus, 148
of surgical neck of humerus, 104
of tibia alone and of tibia and femur combined, 672
in relation to fractures, 22
of spine, 336
of traumatic lesions of atlas and axis, 350
Ruth, C. E., 479, 505

Sacro-iliac joints, 427
dislocation, 429, 433
Sacrum, fracture of, 429
isolated fracture of, 445
Saddle-nose, traumatic, 395
Sayre apparatus, 70
Scaphoid, carpal, dislocation of, 304
fracture of, 250, 295, 304
causation, 296
diagnosis, 297
mechanism, 296
non-union, 299
operative excision, 299
roentgenological examination, 298
treatment, 298
varieties, 297
tarsal, 762
Scapula, anatomy, 59
fracture of, 78
diagnosis, 78
radioscopy, 79
treatment, 79
varieties, 78
neck of, 79
diagnosis, 80
displacement, 79
treatment, 80
method of fixation in compound fractures of, 58
Schurmeier, H. L., 264
Scudder, 586
Semilunar, carpal, dislocation of, 250, 301, 304
diagnosis, 301
excision, 303

Semilunar, carpal, dislocation of, mechanism, 301
treatment, 301
fracture of, 304
cartilage, external, of knee-joint, injury of, 623
of knee-joint, anatomy, 581
injury of, 578, 620
after-treatment, 626
causation, 620
diagnosis, 623
of old injuries, 624
of recent injuries, 623
excision of cartilage, 626
Jones method of reducton, 625
mechanism and pathology, 622
reduction, 625
Sesamoid of great toe, fracture, 769
diagnosis, 769
treatment of old fracture, 771
of recent fracture, 770
Shoulder, compound injuries in region of, 127
dislocation of, 89
after-treatment, 95
causation, 89
diagnosis, 91
dislocation associated with fracture, 98
Kocher's method of reduction, 94
mechanism and varieties, 90
old-standing dislocation, 97
posterior dislocation, 90
prognosis, 95
traction method of reduction, 95
treatment, 93
of dislocation associated with fracture, 99
fixation of, in fracture of ribs, 420
girdle, anatomical considerations, 59
examination of, 62
injuries of, 59
muscles, 62
-joint, anatomy of, 83
movements of, 86
muscles of, 83
optimum functional position of, 86
synovial relations of, 85
method of fixation in compound fractures of, 58
recurrent dislocation of, 96
etiology, 96
mechanism, 96
treatment, 96
Sinclair skate, 664, 672, 728
Sinclair's glue, 14
Skeletal traction, 15
Skillern, 634
Skin, care of, in lesions of spinal cord, 388
traction, 13
Smith, H. L., 183, 197
S. Alwyn, 630
and Jones, R., 631
Smith-Petersen incision, 470, 482, 510
Smith's fracture of radius (Colles's fracture reversed), 250, 263, 290
Speed, K., 483, 491, 513
Spinal cord, injuries of, associated with fractures and dislocations of vertebral column, 343, 373
diagnosis, 376
lumbar puncture, 377
pathology, 374
prognosis, 382
treatment, convalescent, 391
immediate, 384
remote, 388
partial lesions of, 382
Brown-Séquard syndrome; irregular lesions; root lesions, 382
total transverse lesions of, 378
bladder and rectal disturbances, 379
clinical features, 378
lesions in dorsal region, 381
of cauda equina, 381
of cervical enlargement, 380
of lumbar enlargement, 381
Spinal fracture, correct position in, 340
Spine, anatomy of, 327
anatomical variations in, 337
articular process of, isolated dislocation, 343
fracture, 343
diagnosis, 343
treatment, 343
articulations of, 327
cervical dislocation, 343
compression fractures of, 342, 363
dorsal and lumbar, dislocations of, 347
ligaments of, 327
method of fixation in compound fractures of, 58
movements of, 334
optimum position for fixation of, 338
physiologic curves of, 327
roentgenological examination of, 336
surface anatomy of, 334
total dislocation and fracture-dislocation of, 343, 372
clinical features, 373
pathology, 373
treatment, 374
transverse processes of, isolated fracture, 343, 358
diagnosis, 359
mechanism, 358
prognosis, 359
treatment, 359
Spinous process or laminæ, isolated fracture of, 343, 355
diagnosis, 355
treatment, 355
Splint, aeroplane, 58, 107, 111
application of, in fracture of shaft of femur, 534
army transport, 28
adaptation of, 30, 31, 513, 667
banjo traction, 58
Cabot posterior wire, 31, 32, 38, 610
caliper, in fracture of femur, 567

Splint, Cleary aeroplane, 112
coaptation, 142
convalescent, in fracture of shaft of humerus, 148
Crile traction, 58, 519
Delbet plaster, 676
hand and wrist, 33
Hodgen's, 493
in fracture of metatarsal bones, 767
interdental (Hammond) 408
Jones humerus traction, 31, 58, 136, 199
long Liston, 31, 33
methods of applying for emergency use, 32
modified hinged, 137
pillow and side, 36
plantar, 58
plaster gutter, in Colles's fracture, 277
in fracture of both bones of forearm, 231
posterior, in reducing fractures of tibia alone and of tibia and fibula combined, 661
posterior plaster, in fracture of lower end of humerus, 187
preparation of, in fracture of shaft of femur, 548
standardization of, for civilian use, 28
suspension of, in fracture of shaft of femur, 536
of humerus, 142
of surgical neck of humerus, without displacement, 109
Thomas arm, 30, 31, 38, 107, 110, 120, 127, 153, 195
(hinged type), 32
in compound fractures of tibia and fibula, 687
leg, 30, 31, 513, 667
(half-ring or whole-ring type), 32 519, 532
ring caliper, 501, 511
traction, 13
in fracture of both bones of forearm, 234
triangular axillary, with forearm rest, in fracture of shaft of humerus, 148
wooden and anterior angular, in fracture of both bones of forearm, 231
in Colles's fracture, 277
Splinting, emergency or primary, of fractures, 28
in fracture of ankle, 713
of both bones of forearm, 230
Spondylitis, traumatic (Kümmell's disease), 271
Spondylolisthesis, congenital, 351
traumatic, 343, 351
diagnosis, 354
treatment, 354
Sprain-fracture of knee, 619
Steinmann's pin, 546, 560, 585, 671, 728
Step-cut operation in fracture of shaft of humerus, 151
Stern, W. G., 302
Sternoclavicular dislocation, 72
mechanism, 73
treatment, 73
joint, anatomy of, 59
Sternum, anatomy, 412
fracture of, 412
causation, 421
diagnosis, 422
Stiles, Sir Harold, 347
Stimson's method of treating dislocation of hip, 466
Stoffel, A., 391
Subarachnoid bleeding, 377
block, 377
Subastragaloid dislocation, reduction of, 761
Subclavicular dislocation, 90
Subcoracoid dislocation, 90
Subglenoid dislocation, 90
Surls, J. K., and Osgood, R. B., 617, 635, 636
Suspension, 16
of splint in fracture of shaft of femur, 536
of humerus, 142
of surgical neck of humerus without displacement, 109
traction, Blake, 58, 128
Sustentaculum tali, fracture of, 731, 745
after-treatment, 748
diagnosis, 747
prognosis, 747
reduction, 747
Suture, primary, delayed primary, and secondary, 41
Swathe, Lund, 188, 202
Symphysis of jaw, fracture of, 405
pubis, 427
separation of, 429, 432

"T" fracture (or intercondyloid fracture) of femur, 584
manipulative correction with clamp in, 586
operative fixation in, 587
skeletal traction, 585
treatment, 584
Tarsal and tarso-metatarsal joints, anatomy, 733
Tarso-metatarsal dislocation, 764
treatment; varieties, 764
Tarsus, anterior, fracture of bones of, 762
fracture of other tarsal bones; fracture of scaphoid; treatment, 762
Tetanus, prophylaxis of, 50
Thomas arm splint, 30, 31, 38, 107, 110, 120, 127, 153, 195
(hinged type), 32
collar, 351, 369
heel, 710

Thomas heel, in fracture of tibia alone and of tibia and fibula combined, 679
Hugh, 13, 183
leg splint, 30, 31, 38, 513, 549, 556, 557, 571, 577, 585, 586, 593, 595
(half-ring or whole-ring type), 32, 519, 532
ring caliper brace, 501, 511
splint and its adjustment in fractures of tibia alone and of tibia and fibula combined, 672
in compound fractures of tibia and fibula, 687
injuries of ankle, 728
wrench, 302
Thorax, anatomy of, 412
injuries of, 412
intrathoracic complications in, 412, 422
hæmothorax, 422
pneumothorax, 423
subcutaneous emphysema, 423
treatment, 424
vessels and nerves of, 412
Thumb and palmar arches, anatomy, 260
carpo-metacarpal joint of, luxation, 305
compound injuries of fingers and, 250, 321
proximal phalanx of, anatomy, 314
dorsal luxation, 250, 314
causation, 314
fixation, 316
pathology, 314
reduction, 315
Tibia and fibula, anatomy of lower end of, 689
fractures of, involving ankle-joint, 689, 697
by abduction of foot (Pott's fracture), 689, 699, 700, 711
mechanism and pathology, 700
methods of closed reduction, 711
by adduction of foot, 689, 699, 701, 711
mechanism and pathology, 701
methods of closed reduction, 711
by external rotation of foot, 689, 699, 711
mechanism and pathology, 699
methods of closed reduction, 711
by posterior displacement of foot, 689, 699, 702, 711
mechanism and pathology, 702
methods of closed reduction, 711
classification according to mechanism, 697
varieties, 697
shaft, fractures of, 638
combined, compound fractures, treatment, 683
fractures of, continuous traction method in, 663
after-treatment, 673
convalescent stage, 674
delayed union, 680
Delbet plaster splint, 676
duration of use of splint, 679
fixed and sliding traction, 672
glued stocking, 664, 669
malunion, 679
methods of obtaining traction, 664
non-union, 682
open reduction, 679
physiotherapy, 673
protected weight-bearing, 674
purpose of traction, 663
roentgenologic examination, 672
short caliper brace, 678
Sinclair skate, 664
skeletal traction, 670
Thomas heel, 679
Thomas splint and its adjustment, 672
time required for union, 673
Tibia, fractures of, continuous traction method in, 663
after-treatment, 673
convalescent stage, 674
delayed union, 680
Delbet plaster splint, 676
duration of use of splint, 679
fixed and sliding traction, 672
glued stocking, 664, 669
malunion, 679
methods of obtaining traction, 664
non-union, 682
open reduction, 679
physiotherapy, 673
protected weight-bearing, 674
purpose of traction, 663
roentgenologic examination, 672
short caliper brace, 678
Sinclair skate, 664
skeletal traction, 670
Thomas heel, 679
splint and its adjustment, 672
time required for union, 673
dangers in reduction, 656
effect of alteration of normal weight-bearing lines in, 651
fundamental rules in treatment, 652
gravity method of reducing, 660
indications for closed reduction, 658
methods of obtaining alignment in, 658
posterior splint method of reducing, 661
reduction and fixation method of treatment, 654
relation of, to function of foot, 650
technic of reduction, 658
time element in reduction, 655
traction method of reducing, 658
treatment, 650
tuberosities of, 578, 590
convalescent brace, 595
displacement, 592
excision of knee, 595
movements of knee, 593
operative fixation, 594
reduction with aid of clamp, 593

Tibia, tuberosities of, treatment by extension and early movement, 592
treatment of fracture with slight deformity, 595
Tibial spine, fracture of, 578, 617, 630
diagnosis, 631
treatment, 631
types and causation, 630
tubercle, separation of, 578, 599
diagnosis, 600
treatment, 600
Tibio-astragaloid articulation, anatomy, 689
Tibio-fibular articulation, superior, anatomy, 639
Todd, A. H., 254, 296, 298
Toe-drop in lesions of spinal cord, 390
Toes, anatomy of, 733
method of fixation in compound fracture of, 58
phalanges of, fracture, 768
dislocation, 772
Traction, adhesive, in fracture of shaft of humerus, 142
Blake suspension, 58, 128, 214
continuous, in fracture of both bones of forearm, 233
of tibia alone and of tibia and fibula combined, 670
elbow, in fracture of shaft of humerus, 141
finger, 326
fixed and sliding, in fracture of shaft of femur, 540
of surgical neck of humerus, with displacement, 109
of tibia alone and of tibia and fibula combined, 672
in fracture of acetabulum with intrapelvic displacement of head of femur, 477
of both bones of forearm, 247
of metatarsal bones, 767
in injuries of pelvic ring, 439
in intercondyloid or "T" fracture of lower end of humerus, 199
indications for, 17
Maxwell-Ruth method in fracture of neck of femur, 505
method, 12
of reducing fractures of tibia alone and of tibia and fibula combined, 660
of reduction of shoulder dislocation, 95
purpose of, 12
skeletal, 15
in fractures of ankle, 720
of os calcis, 755
of shaft of femur, 546
advantages of, 554
dangers, 551
of tibia alone and of tibia and fibula combined, 670
to upper end of tibia, 560
skin, 13, 533
splint, banjo, 58
Crile, 58
Jones humerus, 136
Thomas, 127
splints, 13, 58, 519, 532
Transportation, dangers of, without adequate fixation, 27
Treatment, functional viewpoint in, 1
methods of, 6
massage and mobilization, 6
open operative reduction, 6, 18
reduction and fixation, 6
traction, 6
need of immediate, 3
of fractures and dislocations, functional viewpoint in, 1
summary of, 24
of intra-articular injuries, 54
pathology in relation to, 2
Trochanter, great, fracture of, 515
lesser, fracture of, 517
Trochanters, fractures of, 447, 515
Truesdell, E. D., 5

Ulna, anatomical considerations, 154, 215
coronoid process of, fracture, 154, 206
fracture of shaft of, associated with dislocation of head of radius, 222
causation, 222
diagnosis, 222
treatment, 240
luxation of, in Colles' fracture, 283
olecranon process, fracture of, 154
diagnosis, 211
fixation, 212
mechanism, 205
pathology, 211
treatment, 211, 213
posterior dislocation of radius and, 154
shaft of, fracture, 215
causation, 220
complications, 240
diagnosis, 221
displacement, 220
prognosis, 240
treatment, 237
Union, delayed, 20
in fracture of shaft of humerus, 150
of tibia alone and of tibia and fibula combined, treatment, 680
fibrous *versus* bony, in fracture of patella, 604
Urethra, injury of, in injuries of pelvis, 433

Velpeau bandage, 70
Vertebral bodies, compression fracture of, 343, 363
fixation, 368
operative treatment, 369
pathology, 363
production, 363

Vertebral bodies, roentgenologic examination, 366
treatment, 367
column, anatomical considerations, 327
injuries of, 341
injuries of spinal cord associated with fractures and dislocations of, 343
diagnosis, 376
lumbar puncture, 377
pathology, 374
prognosis, 382
treatment, 374
lesions, association of cord and, 342

Wallace, J. O., 342
Walton, G. L., 344, 350
Whitman method of treatment of fracture of neck of femur, 493, 511
operation in ununited fracture of neck of femur, 512
Royal, 483, 493, 505, 512
Wilensky, 515
Wilson, G. E., 383
Wolff's law, 5
Wound closure, 41, 55
infection, 39
mechanical sterilization of, 40
Wounds, after-care of, 56
bacterial examination of, 56
contaminated, 48
drainage of, 55
infected, Carrel-Dakin method of treating, 42
local treatment of, 50
old, danger of reinfection in, 46
produced by external violence, 47
by internal violence, 48
uncontaminated, 48
uninfected, treatment of compound fractures with, 51
Wrist and hand, anatomical considerations, 250
injuries of, 250
landmarks in region of, 261
method of fixation in, 58
optimum functional positions of, 261
ossification of, 257
compound injuries in region of, 250, 306
treatment of infection, 306
of deformity, 307
importance of adduction or abduction in fracture of, 264
Wrist-drop in injury of radial nerve, 134
Wrist-joint, anatomical considerations, 250
injuries of, 250, 292

Zygomatic arch and malar bone, anatomy, 397
fracture of, 392
diagnosis, 398
treatment, 398
types, 397